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SPATIAL PATTERNS AND DIVERSITY IN A POST-PLOUGHING SUCCESSION IN HIGH PLATEAU GRASSLANDS (PAMPA DE SAN LUIS, CÓRDOBA, ARGENTINA) *

S. DÍAZ, A. ACOSTA & M. CABIDO

Keywords: Diversity, Grasslands, Ploughing, Spatial organization, Succession

Abstract: Spatial arrangement and diversity along a post-ploughing succession are analyzed in a plateau at 1800 - 1900 m altitude in Central Argentina. Four successional stages were simultaneously studied: I (1 year of abandonment after ploughing), II (3-5 years), III (25 years) and IV (40 years). Detrended Correspondence Analysis and diversity analysis, comprising species diversity, spatial diversity and mean spatial niche width, were applied.

It is concluded that (i) Spatial organization of grassland changes with succession: during early stages vegetation distribution follows a topographical gradient from upper to lower positions on slopes, whereas mosaic patterns prevail in late successional stages. (ii) As succession advances, species diversity increases, making us reject the hypothesis that species diversity decreases with succession as a result of the dominance of the grass *Deyeuxia hieronymi*. This process is associated with a progressive reduction of mean spatial niche width.

Introduction

The aim of this investigation was to describe the variability in spatial distribution of grasslands along a post-ploughing succession in the mountains of Central Argentina. In the upper part of Córdoba mountains, ploughing can only be attained at high plateaus. Consequently, Pampa de San Luis is one of the few areas within the Grassland belt where post-ploughing successional changes can be studied.

Menghi *et al.* (1988a) and Cabido *et al.* (1987) agree that mosaic patterns prevail in mature grasslands from high plateaus at 1000 and 2100 m altitude in Córdoba mountains. This pattern is probably arising from a biological source: the presence of large perennial grasses determinates patches of tall grassland which alternate with lower grassland or turf units.

Acosta (1988) concludes that regardless of altitude, stabilized grasslands on the same substrate tend to exhibit similar organizational patterns. However, in the case of post-disturbance succession, several authors report that grassland structure suffers significant changes (De Pablo *et al.*, 1982; Sterling *et al.*, 1984; Facelli *et al.*,

* There is not a published flora from Central Argentina. When it has been possible, nomenclature follows Cabrera (1963, 1965 a, 1965 b, 1967, 1968 and 1970). Complete list of recorded species in the study area is available for request.

1987). According to them, changes on disturbed grassland communities can be expected not only at species composition level, but also at their spatial arrangement. In consequence, the study of succession in this paper was approached from two viewpoints: floristic composition and diversity parameters.

With respect to species diversity variations in different successional stages, two general models can be mentioned: (i) Authors like Odum (1960), Margalef (1969), Reiners *et al.* (1970), Mellinger and Mc Naughton (1975) predict an increase in species diversity as succession advances, as a result of the progressive reduction of effective niches by competition. (ii) Other authors (Peet, 1974; Glenn-Lewin, 1977; Grime, 1979; Houssard *et al.*, 1980) argue against monotonic diversity increase as succession advances. They favour a decrease of diversity in advanced stages as a consequence of the dominance effect of certain populations within the community. In herbaceous communities, this action is exerted by plants which accumulate large amounts of biomass (Nichols and Monk, 1974; Bazzaz, 1975; Facelli *et al.*, 1987). These plants are "competitors" in the sense of Grime (1979) or "good competitors for light" according to Tilman (1982).

This report is based on the following hypothesis:

- According to Acosta (1988) we may expect a mosaic pattern for the mature stages similar to that exhibited by high plateau grasslands at lower altitudes.

- It is expected that, as a result of ploughing, the mosaic pattern will disappear during early successional stages. It is interesting to find out how long it would take to recover its original structure.

- Changes in spatial organization should be accompanied by variations in species composition, whether they are related to floristic or to relative abundance changes.

- Spatial segregation of species would increase as grassland recovers its original pattern of organization. If so, a decrease in spatial diversity may be predicted, as well as a consequent reduction in the mean spatial niche width.

- The tall tussock grass *Deyeuxia hieronymi* would become dominant during late successional stages. It is interesting to find out which diversity model grassland behaviour matches. Based on the monotonic diversity increase hypothesis, a rising species diversity $H(E)$ can be expected towards late successional stages. As an alternative hypothesis, $H(E)$ would fall due to the influence of dominant *D. hieronymi*, as succession advances.

Study area

Pampa de San Luis is a plateau located at 1800-1900 m altitude in the Central chain of Córdoba mountains, the Sierras Grandes (31° 20' S and 64° 45' W). Relief is slightly undulated, with slopes around 5-7%. It has a thick layer of modern sediments, which makes horticulture and introduction of forage species possible through tilling. There are no climatic records for the area. However, Cabido *et al.* (1988) defined the climate, according to Koeppen (1948) as temperate rainy, with dry cold winter and short cool summer.

From a phytogeographical point of view, the area has been included by Luti *et al.*

(1979) in the Grassland belt, the upper vegetation zone of Córdoba mountains. Agriculture use has brought about a vegetation complex with several post-disturbance situations. Cabido *et al.* (1988) describe the vegetation of Pampa de San Luis and discuss successional status of surveyed communities. They suggest that the community dominated by the tall tussock grass *D. hieronymi* (a typical member of the Grassland belt) is the closest to potential vegetation within the area.

Methods

Experimental design

A static approach (*sensu* Austin, 1977) was carried out: simultaneous sampling of neighbouring areas with different time of abandonment, which reduces the effect of climatic variations and enables to obtain satisfactory results in just one sampling period. Samples were taken in summer, during January, in order to prevent phenological differences among them.

Four different post-ploughing situations were found: stage I (1 year of abandonment after ploughing), stage II (3-5 years), stage III (25 years) and stage IV (40 years). The absence of intermediate stages between III and IV is due to the recently renewed interest in agricultural activities which was dropped in the 60' and reactivated only five years ago. All grasslands sampled were free of grazing and had not been burnt in the last ten years.

For general sampling design, criteria already applied in grassland surveys in Córdoba mountains were used (Menghi *et al.*, 1988 a, 1988 b; Acosta, 1988). For each successional stage, sites including complete slopes of about 5% inclination were considered, in order to allow the expression of geomorphological dynamics. Stratified sampling based upon phytophysiological features was applied to the four stages. Within each stage, 3 x 5 m sampling plots were placed. Presence of plant species was recorded in all eight 20 x 20 cm sampling quadrats randomly distributed within each sample plot. The final expression of species abundance was a frequency value, ranging from 0 to 8. Details of sampling design are shown in Table 1.

Data analysis

Floristic composition and some aspects of spatial arrangement were analyzed by means of Detrended Correspondence Analysis (DCA) (Hill and Gauch, 1981). Diversity parameters were studied following Pielou (1975, 1977) and Pineda *et al.* (1981) guidelines. According to these authors, total diversity may be subdivided into uncertainty about species richness and evenness $H(E)$, as well as uncertainty about spatial distribution of them within the community $H(P/E)$, defined as spatial or pattern diversity. The expression $A = H(P/E) / \log_2 N$, being N the number of plots, is considered by De Pablo *et al.* (1982) as the mean width of spatial niche and is similar to niche width proposed by Pielou (1977).

SUCCESIONAL STAGE	SAMPLING STRATA	PLOTS	ELEMENTARY SAMPLING UNITS	
I	upper sectors	4	32	
	lower sectors	4	32	
II	upper sectors	4	32	
	intermediate sectors	2	16	
	lower sectors	4	32	
III	upper sectors	tall grassland	2	16
		short grassland	2	16
	lower sectors	tall grassland	2	16
		short grassland	2	16
IV	upper sectors	tall grassland	3	24
		short grassland	3	24
	lower sectors	tall grassland	3	24
		short grassland	3	24
TOTAL		38	304	

Table I — Design of sampling carried out in Pampa de San Luis, in four successional stages, recorded in a single growing season: I = 1 year of abandonment after ploughing; II = 3-5 years; III = 25 years; IV = 40 years.

Results and discussion

Floristic analysis

Figure 1 shows the projection of sample plots on the plane defined by the first two DCA axes. It may be noticed that axis I discriminates different successional stages: on the right extreme, stage I plots (1 year after abandonment) are concentrated; towards left, stage II plots (3-5 years) appear clearly separated from stages III and IV plots (25 and 40 years of abandonment, respectively). Stages III and IV plots are distinguished by axis II of DCA. Floristic heterogeneity within each stage (reflected on plots dispersion) diminishes as succession progresses.

Table 2 shows species associated to each successional stage defined by means of DCA. It may be noticed that stages I, II and IV are characterized by the occurrence of several "exclusive" species (*i.e.* species found in only one successional stage). For stage III only one "exclusive" species can be mentioned, and a few associated ones, even though there are several associated species shared with stages II and IV. The number of "exclusive" species is the same for stages I, II and IV. However, when comparing it with the total number of species found in each stage, it is found that

STAGE I	STAGE II	STAGE III	STAGE IV
N° species: 42 % "exclusive" species: 19	N° species: 69 % "exclusive" species: 10	N° species: 54 % "exclusive" species: 1.25	N° species: 95 % "exclusive" species: 7.4
* Muhlenbergia ligularis * Zephyranthes longistyla * Glandularia dissecta * Nierenbergia hippomanica * Polygonum aviculare * Lepidium bonariense * Solanum sp. * Euphorbia sp.	* Gallinsoga parviflora * Ambrosia tenuifolia * Verbena littoralis * Medicago lupulina * Chenopodium chilense * Carduus nutans * Brassica rapa subsp. sylvestris Acicarpa tribuloides Cyperus phaeocephalus Cyperus manimae Heimia salicifolia Plantago lanceolata	* Paspalum dilatatum Eleocharis dombeyana Cyperus reflexus Carex macrorrhiza Eryngium agavifolium Geranium patagonicum Deyeuxia hieronymi	* Gentianella achalensis * Sorghastrum pellitum * Stipa filiculmis * Bromus auleticus * Poa resinulosa * Carex boliviensis * Grindelia globulariaefolia Bothriochloa saccharoides Stipa trichotoma Pratia hederaceae Cuphea glutinosa Bidens triplinervia var. macrantha

* "exclusive" species (species recorded exclusively in one successional stage)

Table 2— Associated species to four successional stages in Pampa de San Luis: I = 1 year of abandonment after ploughing; II = 3-5 years; III = 25 years; IV = 40 years.

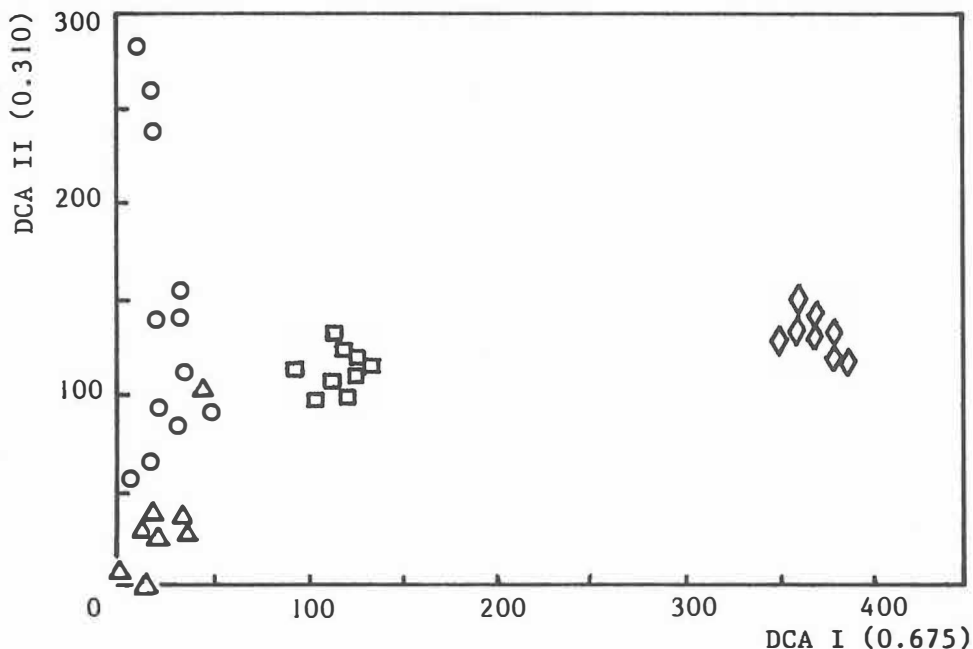


Figure 1 — Ordination (DCA) of sampling plots from four successional stages after ploughing in Pampa de San Luis. Symbols indicate age of abandonment: \diamond = 1 year; \square = 3-5 years; \triangle = 25 years; \circ = 40 years. Eigenvalue corresponding to each axis is indicated in brackets.

floristic change is more evident for stage I, decreasing throughout III and IV. For stage II, floristic change is very low, since only 1.25% of species is not found within other stages of succession.

During early stages (I and II), floristic changes occur, with species typical for each particular age of abandonment. Later on, these changes become gradual, with rearrangement of shared species (stage III) until a definite floristic composition is reached again in stage IV.

Spatial arrangement analysis

Figure 2 shows the projection of plots corresponding to the four successional stages individually considered on the plane defined by the first two axes of DCA. Figure 2 A corresponds to stage I, where no spatial structure is clearly defined. Yet, there is a weak trend along the first axis to distinguish upper and lower topographical positions on slopes.

During stage II (Figure 2 B) there is a clear discrimination along axis I of upper and lower positions, within a physiognomically homogeneous grassland.

Stage III (Figure 2 C) evidences a similar segregation of upper and lower sectors on slopes along the first DCA axis. However, two different patches can be distinguished along axis II: plots from short grassland and those corresponding to

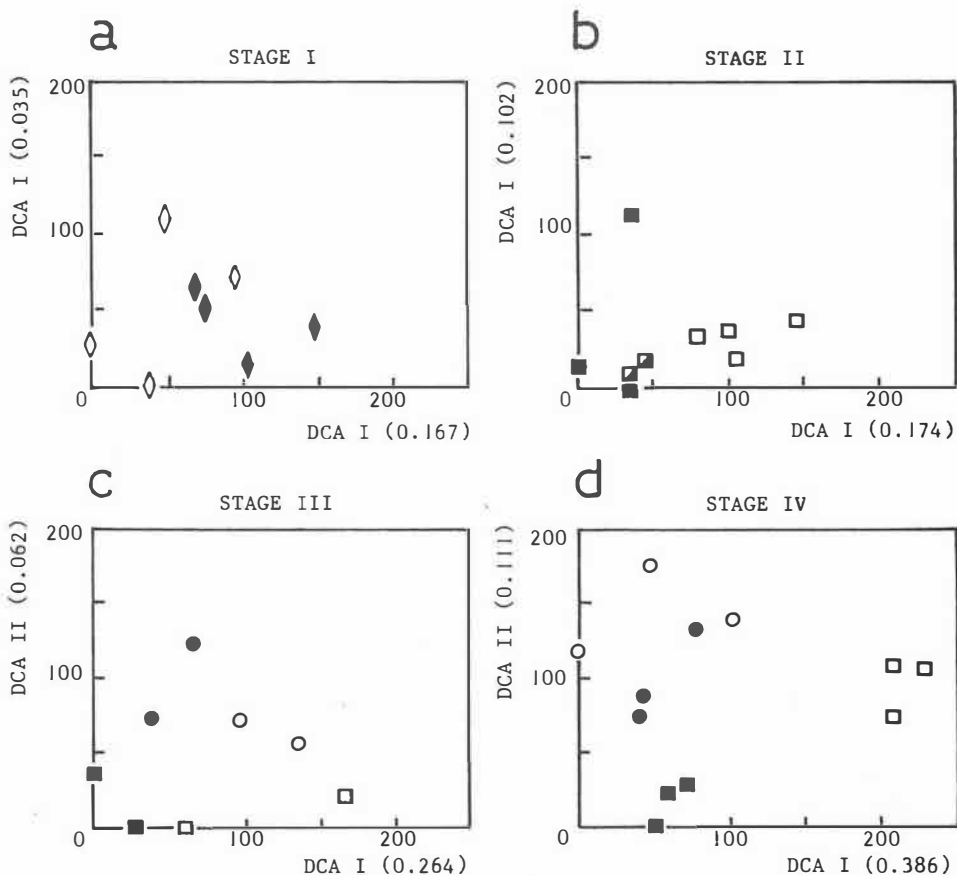


Figure 2 — Ordination (DCA) of sampling plots from four successional stages after ploughing individually considered, in Pampa de San Luis. Rhombs = vegetation of recently ploughed areas; squares = short grassland; circle = tall grassland. Open symbols refer to upper sectors on slopes; solid symbols, to lower sectors; half-solid symbols, to intermediate sectors. Eigenvalue corresponding to each axis is indicated in brackets.

D. hieronymi tall grassland.

Finally, in stage IV (Figure 2D), DCA first axis tends to draw apart short grassland patches from tall grassland ones, whereas axis II separates upper and lower topographical positions. This successional stage, which comprises the most stabilized situation found in the area, shows the typical pattern exhibited by high plateau grasslands reported for other altitudinal levels in the mountains of Córdoba (Cabido *et al.*, 1987; Menghi *et al.*, 1988 a). These results agree with those of Acosta (1988), who pointed out that stabilized grasslands communities on the same geological substrate exhibit similar spatial patterns regardless of the altitude.

Changes in grassland spatial organization along time suggest that the main factors conditioning its arrangement are not the same in different successional

stages. Ploughing eliminates coarse-grained mosaic typical of late stages, replacing it by a different design, that follows topographical gradient and is related to water and nutrients flow from upper exportation areas toward lower accumulation ones. This process is favoured by ploughing carried out following topographical gradient, with furrows running down slope.

Spatial arrangement of vegetation is reestablished with time, and during stage III the pattern closely resembles that of a stabilized grassland. However, mosaic pattern is not so definite as for stage IV, and several floristic differences still remain.

The trend of structural change detected in this study is in agreement with the general guidelines of Pineda *et al.* (1981), De Pablo *et al.* (1982), Sterling *et al.* (1984) and Peco and Pineda (1987), particularly in relation to the drastic disturbance in grassland spatial patterns caused by ploughing. It is worth noticing, however, that in the cases reported by these authors the final result is not a mosaic, but a structure related to the topographical gradient, since spatial organization of grasslands seems to be basically determined by the nature of the substrate.

Structural analysis of different successional stages is complemented with analysis of spatial diversity, shown on Figure 3. Pattern diversity diminishes as succession advances. This fact supports the prediction of a higher spatial heterogeneity, and consequently a higher segregation of species, towards late successional stages. Results agree with those reported by De Pablo *et al.* (1982), Sterling *et al.* (1984) and Peco and Pineda (1987). Mean spatial niche width decreases with succession, suggesting an increasing in the proportion of specialist species from a spatial viewpoint. Further analysis should elucidate whether there are generalist species in the first stages, which are replaced by specialist ones as succession advances, or else the same species behave as generalists or specialists at different stages, modifying their spatial niche width as resources distribution changes.

Species diversity analysis

Species diversity $H(E)$ shows a general trend towards increase from early to late successional stages (Figure 3 A), thus rejecting the idea of the dominance effect of *D. hieronymi* and the consequent exclusion of other species.

An analysis of plots belonging to tall grassland patches leads to convergent results: specific diversity rises with succession, showing there is no progressive exclusion of species even within tall grassland patches (Figure 3B). Large perennial grasses might bring about certain microhabitat conditions (such as water and nutrients uptake, protection, spatial support) that would favour an increase in species diversity. Similar results (specific diversity increase during advanced successional stages with the occurrence of tall tussock grasses) have also been reported by Menghi *et al.* (1988 b).

The progressive increase in diversity, together with the decrease in mean spatial niche width would support the ideas of several authors (Odum, 1960; Margalef, 1969; Reiners *et al.*, 1970; Mellinger and Mc Naughton, 1975), about diversity

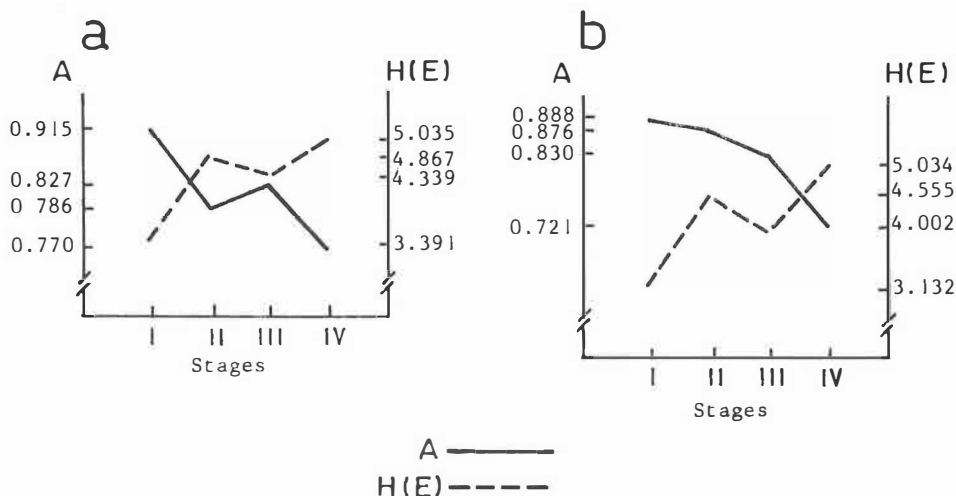


Figure 3 — Mean spatial niche width (A) and species diversity [$H(E)$], of Pampa de San Luis grasslands, in four successional stages after ploughing: I = 1 year of abandonment, II = 3-5 years; III = 25 years; IV = 40 years. In 3 A every recorded plots are considered; in 3 B only tall grassland patches with *Deyeuxia hieronymi* are analyzed.

monotonic increase as succession advances. It may happen that stage IV has not yet overcome the inflexion point of diversity curve suggested by the second model, and predicted diversity decrease might occur in later successional stages. After several years, *D. hieronymi* might advance over the short grassland, changing the mosaic appearance into that of a continuous tall grassland. This finding would be supported by the presence of small *D. hieronymi* individuals out of tall grassland patches. Further studies on successional behaviour of these grasslands should test these assumptions and whether the changes, if any, are related to a fall in species diversity as result of dominance.

Conclusions

- Typical mosaic spatial arrangement found in plateaus at 1000 and 2100 m also occurs in stabilized grasslands at 1800-1900 m altitude. This finding supports the idea that the nature of the substrate is the main factor conditioning grassland spatial arrangement in Córdoba mountains.

- Spatial organization of stabilized grassland is eliminated by ploughing and does not restore during the first five years of abandonment. Later on, the arrangement tends to recover. However, after twenty five years of abandonment, floristic and diversity differences remain.

- Differences in species composition among successional stages are predominantly expressed as floristic changes, mainly during early stages. As succession progresses, spatial rearrangement of shared species becomes more significant, so increasing their habitat segregation and showing higher specialization from a spatial

viewpoint.

-Species diversity rises with succession. Therefore, no evidence of *D. hieronymi* is observed that might prevent coexistence with other species within grassland.

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(Manuscript accepted 30.10.1988)

THE VEGETATION OF ROCK FISSURES, SCREES, AND SNOW-BEDS IN THE PIRIN PLANINA MOUNTAINS (BULGARIA)

Ladislav MUCINA, Milan VALACHOVIČ, Ivan JAROLÍMEK, Ján ŠEFFER, Anna KUBINSKÁ
& Ivan PIŠŮT

Keywords: alpine vegetation, Bulgaria, endemic plants, syntaxonomy, *Asplenietea trichomanis*, *Salicetea herbaceae*, *Thlaspietea rotundifolii*

Abstract: The vegetation of calcareous rock fissures and crevices, marble screes, and snow-beds on granite, marble and lime-rich schists was studied in the Pirin Planina Mts., SW Bulgaria. Three plant communities of the rock-fissure vegetation were described, including the *Hieracio pannosi-Caricetum*, *Leontopodio-Potentilletum stojanovii*, and the *Silene pusilla-Saxifraga oppositifolia* community (both in subalpine and alpine altitudes). The syntaxonomic relations of the communities to the *Ramondion nathaliae* were discussed. The scree vegetation on marble in the alpine belt is represented by the *Papaveri-Armerietum* (with several subassociations and variants) which populates shady and moist habitats, and the *Veronico kellereri-Silenetum prostratae* growing on sunny, dry, south-facing screes. They were classified within a new alliance, the *Veronico-Papaverion degenii*, an endemic unit for Bulgaria. The low-altitude screes were classified within the *Bromo lacmonices-Geranium macrorrhizi* (*Silenion marginatae*). Snow-bed vegetation on silicate bedrock belongs to the *Salicion herbaceae*. The *Ligustico-Plantaginetum gentianoidis* (concave relief forms, long-lasting snow cover) and the *Omalotheco-Alopecuretum gerardii* (convex relief forms, short-lasting snow cover), were described from this alliance. The marble snow-beds in the Pirin Planina Mts. are classified within the *Salicion retusae* which includes two associations such as the *Bartsio-Salicetum reticulatae* and *Gentiano-Plantaginetum atratae*, characteristic of the long-lasting and short-lasting snow patches, respectively. All of the associations, but the *Leontopodio-Potentilletum stojanovii* and *Ligustico-Plantaginetum gentianoidis*, were described as new. All of the communities house many species endemic to the Pirin Planina Mts., Bulgaria and Balkan Peninsula.

1. Introduction

The high-mountain vegetation of the Balkan Peninsula is an amazingly varied system of "cold islands in the sea of warm air". It is assumed that during the Pleistocene the psychrophilous and oligothermic vegetation in the Balkan Peninsula covered larger areas, and these might have been interconnected also with the Alps and Carpathians. Although the Continental Glacier was not reaching as far as the Balkans, there were many local glaciers covering particular mountain ranges of the Rodopi-Dinarid Region (Frenzel 1967).

After the retreat of the glaciers to higher altitudes and their decay, the territory covered by psychrophilous vegetation shrunk and "an archipelago of the cold islands in the sky" emerged. These geological and climatical processes gave push to allopatric speciation in these small areas and many endemic plants were formed or

old relict species were saved (Walter & Straka 1970).

The "archipelago" is an excellent example of evolutionary laboratory well-suited for studies of vicariance-biogeography aspects as well as vegetation-chorologic phenomena (Horvat et al. 1974, Krahulec 1985). As the alpine and subalpine vegetation of the Balkans is better preserved than that of the Alps, the Carpathians or the Scandinavian mountains, it is also more diversified. This is also reflected in abundance of endemic alliances, orders, and in Greece even classes (Quézel 1964).

The syntaxonomy of the high-mountain vegetation in the Balkans was performed especially in those countries where the Braun-Blanquet approach of floristic-sociological classification of vegetation set up stable roots. These countries include also Yugoslavia where Horvat and many of his pupils and colleagues elaborated the mountain vegetation in numerous papers (for references see Horvat et al. 1974). Much syntaxonomic work has been done in Rumania in the high-mountain areas (Domin 1933, Borza 1959, Puşcaru-Soroceanu et al. 1963, 1981, Boşcaiu 1971, Sanda et al. 1977, Schneider-Binder & Voik 1977, Resmeriţă & Pop 1984, Coldea 1984, 1985, volume of *Comunicări de Botanică*, Bucureşti, 1977, to mention some important ones). There are a few syntaxonomical papers on the high-mountain vegetation also from Greece (Quézel 1964, 1967). In Bulgaria, on the other hand, vegetation scientists were using other methods of vegetation classification (see for instance Bondev 1959, 1966, Ganchev 1963, Juhász-Nagy 1963, Kochev 1967, Kochev & Nikolov 1976 etc.).

The Pirin Planina Mts. is touristically one of the most popular high-mountain resorts of Bulgaria (the Vihren Mt. is considered the National Mountain). A national park was declared to preserve the nature of this unique area, and this park was included into the list of Biosphere Reserves (Goodier & Jeffers 1981). In 1958 a seminal paper by Simon was published on the alpine vegetation of the Pirin Planina Mts. This paper remained, however, the only reliable published information on floristic-sociological syntaxonomy of the mountains till today.

Our paper is aimed to supply data on other alpine and subalpine vegetation types of the Pirin Planina Mts. than those given by Simon (1958), and to present a syntaxonomical discussion on the described vegetation types. Some ideas on synecology of the types were presented elsewhere (Mucina et al. 1986).

2. Materials and Methods

2. 1. Study Area

The Pirin Planina Mts. is situated in the southwestern Bulgaria. It is limited by the valley of the Struma (Strimon) River from the west, by the Predel Saddle from the north, by the Mesta River from the east and by the Parilska Sedlovina Saddle from Slavyanka Mts. It is the third highest mountain range of the Balkan Peninsula. The highest peak reaches 2915 m (Vihren Mt. or El-Tepe Mt.). The total area of the range is 1210 km² (Dushkov 1983). Pirin Planina Mts. is classified into three

parts such as Northern, Central, and Southern. The northern part is situated between the Predel Saddle (1140 m) and the Todorova Polyana Saddle (1883 m), while the central part is divided from the southern one by the Popovi Livadi Saddle (1400 m).

The main mountain range follows the direction NW to SE and ramifies into numerous side-ridges. The NW slopes are very steep, the SE slopes are gentle. The altitudinal belts in the mountains are represented as follows: 600 to 1000 m above sea level - 25%, 1000 to 1600 - 38%, 1600 to 2200 - 24%, and altitudes above 2200 - 13%.

Three of the peaks reach above the altitude 2900 m (Vikhren, Kutelo I - 2907 m and Kutelo II - 2908 m).

The mountain range is a part of the Rila-Rhodopi Massif built of crystalline rocks belonging to an old Thracic-Macedonian Massif, and sedimentary rocks (mainly carbonatic) of the Mesozoic origin. The high-mountain modelation of the relief is a result of the glacial activity of a local glacier in the Pleistocene. The main range of the Pirin Planina Mts. in its northern part is built of granitoid rocks, crystalline schists and marbles. The main area of the latter is situated between the Kabata Saddle (2700 m) and Kamenititsa Saddle (app. 2600 m). The marbles are grey or grey-white, and stratified by dark strips. Due to long-term tectonic activities they are disintegrated and broken (Georgiev 1956).

The climate is typical of high-mountain altitudes as the most of the area (over 75%) is situated at altitudes above 1000 m. The highest altitudes are characterized by low temperature, small yearly temperature amplitude, windiness (the prevailing winds are from W and SW directions), high air humidity, long-lasting snow cover, and intensive irradiation. The average yearly temperature in Sandanski (275 m) is 13.3° C, in Bansko (963 m) 9.0° C. On the contrary, the temperature of the coldest month (January) is - 4.2° C (measured at the Vikhren Cottage). For a comparison, the January temperature in Sandanski (in the Struma Valley) is 3.4° C. The warmest month is August (8.7° C at the Khizha Vikhren (Cottage) and 23.5° C in Sandanski). The total precipitation in the area is much higher than that in the adjacent basins. The Sandanski Basin is characterized by yearly precipitation of 541 mm, the Razloshki Basin by 702 mm, while 1571 mm was ascertained at the Vikhren Cottage. The cloudiness is the highest in May (around 70%). Snow cover lasts from 5 to 6 months. There is a permanent snow field considered the only Balkan glacier in the Golemiya Kazan Circle. The snow cover is very uneven (Mironski et al. 1970).

The rivers, brooks and rills emerging in the Pirin Planina Mts. belong to two river basin. The southwestern slopes are drained by the Struma River while the northeastern slopes are drained by the Mesta River. The largest tributaries of the Struma include the Pirinska Bistritsa, Sandanska Bistritsa, Vlahinska Reka and Melnishka Reka. The Mesta River collects waters of the Byala Reka, Glazne, Retize and Tufcha. The maximal point water stands of the rivers falls within the month of May when the snow fields above timberline are thawing (Mironski et al. 1970).

The Pirin Planina Mts. is well-known for the variety of glacial lakes counting around 176 in summer.

The studied area belongs phytogeographically to the Central European Floristic Region, Balcanic Subregion, Province of *Moesiacum orientale*, region of Pirin (Bondev et al. 1973).

Our phytosociological material comes from the northern part of the area (the crystalline limestone and marble ridge) and some valleys and ridges of the central part (Fig. 1).

2.2. Field Work

The field work was done during 3 phytosociological expeditions to south-Bulgarian mountains (Pirin Planina and Rila Planina Mts.) in July to August in 1978, 1983 and 1984. The relevés were taken from physiognomically relatively homogeneous stands found in homogeneous habitats. The area of the relevés was adjusted to the extent of well-developed stands and kept approximately the same for the same vegetation type.

By sampling seven-grade scale of Braun-Blanquet (1964) ranging from r to 5 was used in 1978, while the grade 2 was subdivided into 2 m, 2 a and 2 b in sampling the alpine vegetation in 1983 and 1984 (according to Barkman et al. 1964).

2.3. Data Treatment

The critical plant taxa were determined according to Flora na Bulgariya (Stoyanov & Stefanov 1948), Flora na NR Bulgariya (Yordanov 1963-1979) and Flora Europaea by Tutin et al. (1964-1980). The nomenclature of phanerogams follows generally Flora Europaea (see Halliday & Beadle 1983 for a list). The nomenclature of mosses follows Frahm & Frey (1983), and that of lichens is according to Wirth (1980).

The abundance-cover classes recorded in the field were unified by using a transformation of van der Maarel (1979) into a scale ranging from 0 to 9. The transformed relevés were entered into community phytosociological tables.

Traditional syntaxonomic methods of the Braun-Blanquet approach, as revised by Westhoff & van der Maarel (1978), were used in the synthetic phase of the work. We adopted character species, differential species and the diagnostic species combination for the characterization and delimitation of the syntaxa, where by also characteristics of habitats were partly taken into consideration as secondary classification criteria.

English romanization was used in transliteration of original Bulgarian names written in cyrilics.

3. Plant Communities

Three groups of plant communities were investigated in the present paper, such as (1) communities of rock rissures of the *Asplenietea trichomanis*, (2) communities

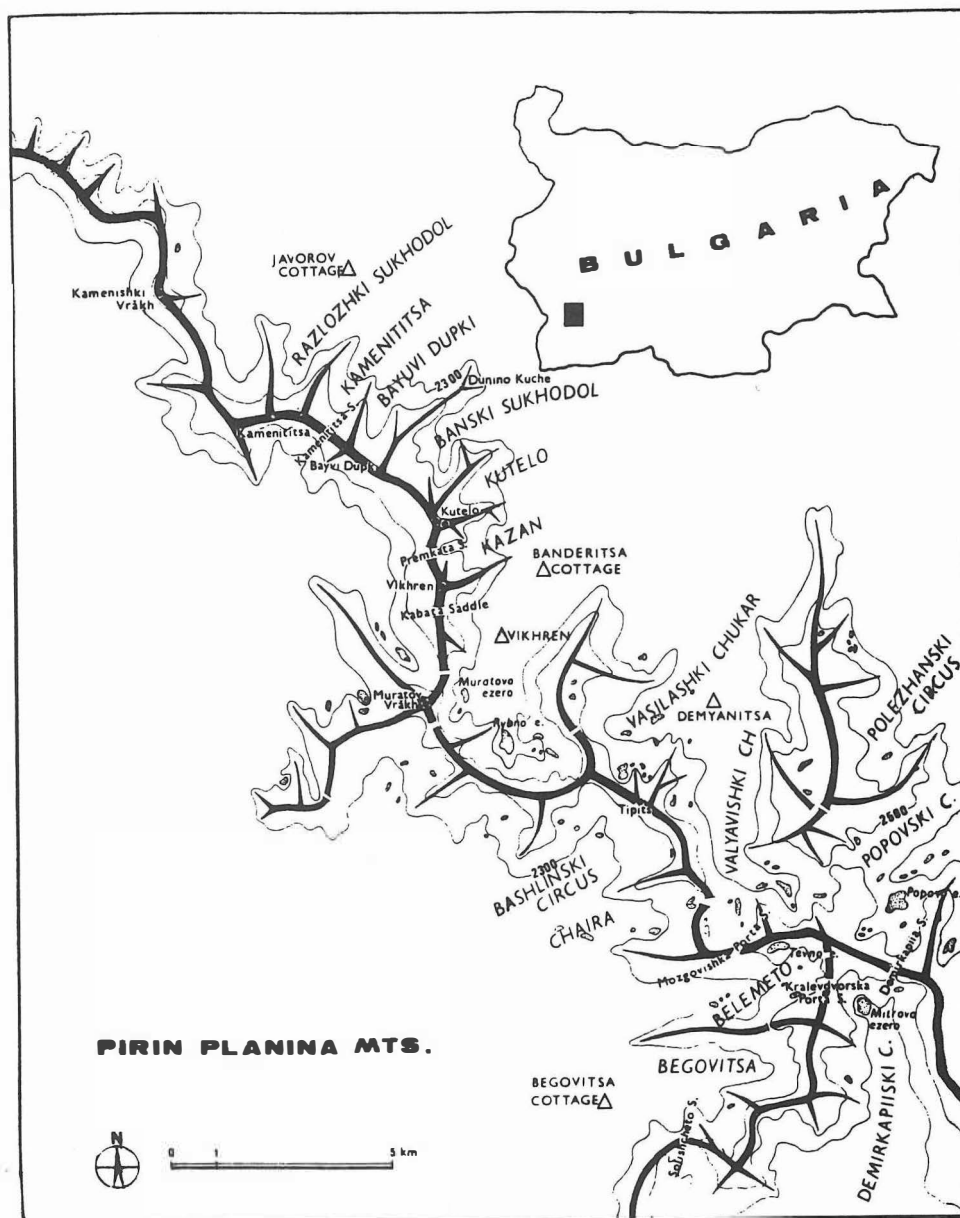


Fig. 1 — A map of the main range system of the Pirin Planina Mts. in southern Bulgaria.

of marble screes of the *Thlaspietea rotundifolii*, and (3) communities of snow beds on siliceous as well as lime-rich bedrocks of the *Salicetea herbaceae*.

3.1. Plant Communities in Rock Fissures and Crevices

In the following paragraphs we bring description and syntaxonomic discussion on plant communities in rock fissures and crevices classified within the *Asplenietea trichomanis*. Only the communities of lime-rich (marble and crystalline limestone schists) in the northern range on the Pirin Planina Mts. were studied. Three communities were distinguished such as the *Hieracio pannosi-Caricetum kitaibelianae* (lower altitudes), *Leontopodio-Potentilletum stojanovii* (higher altitudes), and the *Silene pusilla-Saxifraga oppositifolia* community (schists).

Hieracio pannosi-Caricetum kitaibelianae ass. nova
Nomenclatural type: Tab. 1, relevé 7, hoc loco

The community was recorded at lower altitudes (subalpine and oréal belts) in the close surroundings of the Banderitsa and Vikhren Cottages.

The slopes, rocky ridges and stone walls above the Banderitsa Cottage are formed by crystalline limestones and marbles. At lower altitudes, at around 1900 and 2000 m, these are overshadowed by a *Pinus leucodermis* wood. In the krummholz belt they become exposed to direct insolation and strong winds. The slope aspects and inclination reflect in species distribution pattern. Gentle slopes and broken stony crests are mainly covered by a grassland formation dominated by *Sesleria coerulans* and *Carex kitaibeliana*. Species-rich stands are supported by steep rock faces where the plants dwell in rock crevices and fissures, especially in half-shaded habitats. *Asplenium ruta-muraria*, *A. trichomanes*, *Kernera saxatilis*, *Campanula cochleariifolia* var. *pirinica* Vel. and *Saxifraga paniculata* are typical in these habitats. The open stands of the communities are penetrated by *Sesleria coerulans*, *Hypochoeris pelivanovicii* Petr., *Minuartia verna*, *Helianthemum nummularium* subsp. *tomentosum*, *Euphrasia salisburgensis* and *Paronychia kapela*.

The *Hieracio pannosi-Caricetum kitaibelianae* is limited to eastern aspects of the steep slopes and crests which are rich in fissures and small rocky terraces. The character taxa of the community include *Hieracium pannosum*, *Asperula pirinica* Stoj. et Acht., *Globularia meridionalis*, *Draba lasiocarpa*, *Allium flavum* var. *minus* Boiss. and *Centaurea mannagettae* (Tab. 1, relevés 1-9).

The moss cover is very small (less than 5%); only *Tortella tortuosa* occurs more frequently.

Leontopodio-Potentilletum stojanovii Simon 1958
Nomenclatural type: Simon (1958: Tabelle I, relevé 1), lectotypus

This association replaces the *Hieracio pannosi-Caricetum kitaibelianae* at altitudes above 2300 m. The typical habitats of the community are insulated marble

outcrops and steep, prevailing south-facing, slopes.

Potentilla apennina subsp. *stojanovii* is the dominant taxon of the community. This chamaephytic dwarf shrub forms compact carpets in some places covering also the bare rocks. It is characterized by a stout and branched woody rhizome which as a worm penetrates the fissures and crevices in marble.

The distribution area of *Potentilla apennina* is limited to mountains of the central Apennines (eg. Majella Mts.) and those of the Balkan Peninsula (see below). Flora Europaea (Ball et al. 1968) distinguishes two subspecies, *P. apennina* subsp. *apennina* (Italy) and subsp. *stojanovii* (Bulgaria and Greece). The *Saxifraga-Potentilletum apenninae* was reported from The Šar, Jakupica and Nidža Mts. (Horvat 1936, see also Horvat et al. 1974). Jovanović - Dunjić (1953-1955) described the *Potentillo apenninae* - *Saxifragetum paniculatae* from the Suva Mts. However, the species cannot be considered characteristic of the latter association as it penetrates also other *Ramondion nathaliae* communities, eg. *Erysimo* - *Ramondietum nathaliae* in that region (Tab. 2). Frequent companions are *Campanula cochlearifolia* var. *pirinica*, *Saxifraga juniperifolia*, *Leontopodium alpinum* subsp. *nivale*, *Thymus cherlerioides* and *Helianthemum canum* (Tab. 1, relevés 10-16). Many *Festuco-Seslerietea* species are also found in stands of the *Leontopodio-Potentilletum stojanovii*. Unlike in the *Hieracio pannosi-Caricetum kitaibelianae*, more cryptogams are found in the *Leontopodio-Potentilletum stojanovii*, such as *Tortella tortuosa*, *Hymenostylium recurvirostre*, *Toninia candida*. The average cover of mosses and lichens is 5-10%.

Silene pusilla-*Saxifraga oppositifolia* community

In the area of the Bayuvi Dupki (2820 m) and the Kamenititsa Mt. (2710 m) a rare community *Silene pusilla* - *Saxifraga oppositifolia* is encountered. This community is limited to steep wall outcrops composed of parallel strata of lime-rich schists. The cracks separating the schist blocks are containing plenty of water, thus the bare rock-face (usually from 0.5 to 2 m high) resembles a low-capacity water-spring as the rock-face is soaked with water even when the surrounding habitats are dry.

Several *Saxifraga* (sub) species are found to share the site: *Saxifraga oppositifolia*, *S. adscendens* subsp. *discolor* (Vel.) Kuzm., *S. luteoviridis*, *S. exarata* subsp. *pirinica* (S. Pawl.) Kuzm. and *S. ferdinandi-coburgi* (Tab. 3). All of them have their coenologic optima in other communities (screes, alpine grasslands), but this is probably the only safe site they can grow together. The fissures house small specimens of *Galium stojanovii*, *Asplenium fissum* and *Silene pusilla* which, when in optimal phenological stage, dictate the appearance of the community. The striking species-richness of mosses and lichens is also characteristic of the community. Among other species, the *Thlaspietea rotundifolii* diagnostic taxa, such as *Poa pirinica*, *Veronica saturejoides* subsp. *kellereri* (see Fischer & Fischer 1981), *Papaver degenii* (Urum. et Jáv.) Kuzm., *Thlaspi bellidifolium*, *Arabis caucasica* and *Doronicum columnae* are frequently found here.

Tab. 1 - Plant communities of the Asplenietea trichomanis in the Pirin Planina Mts.

No. of relevés	1111111	C1	C2
	123456789 0123456	%	%
Exposition	E S E NNS S S S S EEEEEEEEEE WSESEEE		
Slope °	755686784 8578786 000500005 0000000		
Sampled area m²	1 1121 2 969272585 9012293		
Cover of herb layer %	656546434 2361634 000000000 5005000		
Cover of moss layer %	<<<< 1 << 1< 111151055 5515505		

HIERACIO-CARICETUM KITAIBELIANAE			
Hieracium pannosum (Ch)	422423432	.....12	100' 29
Hypochoeris pelivanovicii (Ch)	222323332	.....2.	100 14
Asperula suberosa (Ch)	222.23322	.....22	89 29
Carum rigidulum agg. (Ch)	2.233.222	.....2.	78 14
Centaurea mannagettae (Ch)	2222.32.2	.....2	78 14
Allium * minus (Ch)	2222.22..	.....	67 0
Globularia cordifolia (Ch)	..3.53535	.....	67 0
Micromeria cristata (Ch)	22224.2..	.....	67 0
Minuartia verna (D)	3322.4232	.....2	89 14
Teucrium montanum (D)	2243..35	.....	67 0
Helianthemum * tomentosum (D)	2342..22..	..2.....	67 14
Paronychia kapela (D)	32..2.22	.....	56 0
Sedum album (D)	2.23.35..	.....	56 0
Dianthus petraeus (D)	2.2..25..	.....	44 0
Knautia sp. (D)	..2.2..2.2	.....	44 0
Draba lasiocarpa (D)	2..2..2..	.....	33 0
Stipa pulcherrima (D)	....25..3	.....	33 0
LEONTOPODIO-POTENTILLETUM STOJANOVII			
Potentilla * stojanovii (Ch)	.....2.	5583757	11 100
Saxifraga juniperifolia (Ch)	.....	..32..	0 29
Hymenostylium recurvirostre (D)	.....	33..3.	0 43
Fulgensia bracteata (D)	.....	2..22..	0 43
Leskea polycarpa (D)	.....	..22.2..	0 43
Dianthus microlepis (D)	.....	..22....	0 29
ASPLENIETEA TRICHOMANIS			
Carex kitaibeliana	55335.255	6634464	89 100
Helianthemum canum	323355325	33.3433	100 86
Tortella tortuosa	3.232.532	322.534	78 86
Euphrasia salisburgensis	3233332.3	..33..42	89 57
Achillea * aizoon	333254333	..2.3.2.	100 43
Thymus cherlerioides	322..23.2	232..23	67 71
Campanula * pirinica	..2..2..33	222..2	33 57
Encalypta streptocarpa	.....343	22..4..	33 43
Asplenium ruta-muraria	2.22.222.	.....	67 0
Leontopodium * nivale	..2..2.2.	22.2..	22 43
Genista albida	.....3..5	..2.2..	22 29
Jurinea glycyacantha	.....2..22	..2....	33 14
Sedum dasyphyllum	.....222	.....1.	33 14
Kernera saxatilis	.....22.	.....	22 0
Sedum ochroleucum	..2..3..	.....	22 0
Seseli rigidum	..3..2..	.....	22 0
Asplenium trichomanes	.....2.	.....	11 0
Brassica jordanoffi	.....3.	.....	11 0
Iberis pruitii	.....2	.....	11 0
Silene saxifraga	.....2	.....	11 0
FESTUCO-SESLERIETEA			
Saxifraga ferdinandi-coburgi	35333..23	344.454	78 86
Festuca * pirinica	43332433.	3324....	89 57
Sesleria coerulans	3..6.4634	..42.323	67 71
Anthyllis vitellina	..22..2.22	222.22.	56 71

Androsace * arachnoidea	.....25 22....3	22	43
Aster * dolomiticus	...2...2. .2...21	22	43
Hieracium bifidum	...22.22. ....2	22	14
Oxytropis urumovii	332.....	33	14
Poa alpina	.....3..2 .2.2..	22	29
Acinos alpinus	.....2. ....2.2	11	29
Calamagrostis varia	2.....	11	0
Carex sempervirens	.....5	11	0
Centaurea achtarovii	.....2.	0	14
Koeleria eriostachya	.....2.	0	0
Linum extraaxillare	.....2.	11	0
Saxifraga paniculata	.....2..	11	0
Scutellaria alpina	.....3...	11	0
Sedum annuum	.....2	11	0
Silene * graefferi	.....2..	0	14
Silene * pirinica	.2.....	11	0

THLASPIETEA ROTUNDIFOLII

Saxifraga luteoviridis	.2..23332. 123..2.	67	57
Thlaspi bellidifolium	333...3.	44	0
Viola grisebachiana	.....22. ....2.2	22	29
Bromus * lacmonicus	.....332	33	0
Thalictrum minus	.....2.22	33	0
Arabis ferdinand-coburgi	2.....2.	22	0
Senecio rupestris	...2.....	11	0
Saxifraga exarata	.....2.	0	14
Galium stojanovii	.....2....	0	14

SALICETEA HERBACEAE

Sedum atratum	2.....1.	11	14
Dryas octopetala	.....5.	0	14

ERICO-PINETEA

Daphne oleoides	...2...3. ....3.	22	14
Pinus leucodermis juv.	..2..1... ..	22	0

OTHER PHANEROGAMS

Campanula velebitica	.2.2.3... ..	33	0
Sonchus sp.	2.4.....	22	0
Euphorbia cyparissias	2.....2.	22	0
Campanula rapunculoides	2.....2.	22	0
Alyssoides graeca	.....2.	11	0
Pedicularis sp.	.....2.	11	0
Scabiosa cf. webbiana	.....2.....2	11	0
Sempervivum arachnoideum	.....2.....	11	0
Thymus sp.	.....2.....2.	11	0
Carduus scardicus	.....1	11	0
Epipactis helleborine	..1.....	11	0
Juniperus * nana	.....1..	11	0

OTHER CRYPTOGRAMS

Ditrichum flexicaule	..2.2..4. 2.23222	33	86
Hypnum cupressiforme	22..... 2.22...	22	43
Psora decipiens	33.....4 ....4.2	33	29
Squamaria gypsacea	.....4...3 ...23.3	22	43
Toninia coeruleonigricans	.3.....2 ...3...	22	14
Collema sp.	.....2..... 2.....	11	14
Peltigera rufescens	.....22	22	0
Solorina bispora	.....2.2.	22	0
Cirriphyllum tenuinerve	.....2....	0	14
Tortula muralis	.....2...	0	14
Myurella jullacea	.....2....	0	14
Timmia bavarica	.....2....	0	14
Cladonia pocillum	.....2.	0	14
Schistidium apocarpum	.....3....	11	0
Ceratodon purpureus	.....2..	11	0
Grimmia tergestina	.....3....	11	0
Fissidens cristatus	.....3....	11	0
Pseudoleskea nervosa	.....2	11	0
Dermatocarpon miniatum	.....2	11	0
Endocarpon miniatum	.....2	11	0
Placynthium nigrum	.2.....	11	0

Notes: C - constancy; Ch - character species; D - differential species; * - subspecies.

Tab. 2 - Asplenietea trichomanis of the Balkan Peninsula (a short version). The species importance is given in constancy classes according to Braun-Blanquet (1964).

No. of source table	1	2	3	4	5	6	7	8	9	10	11	12	13
No. of relevés per table	8	10	14	7	5	5	7	9	20	10	10	5	2

ASSOCIATIONS OF THE RAMONDION NATHALIAE (Ch & D):

<i>Viola kosaninii</i>	V	*	*	*	*	*	*	*	*	*	*	*	*
<i>Saxifraga scardica</i>	V	*	*	*	II	*	*	*	*	*	*	*	*
<i>Potentilla speciosa</i>	*	V	*	*	*	*	*	*	*	*	*	*	*
<i>Minuartia graminifolia</i>	*	III	I	*	*	*	*	*	*	*	*	*	*
<i>Asyneuma limonifolium</i>	*	II	*	*	I	*	*	*	*	*	*	*	*
<i>Saxifraga marginata</i>	*	*	IV	*	*	*	*	*	*	*	*	*	*
<i>Arenaria cretica</i>	*	*	*	III	*	*	*	*	*	*	*	*	*
<i>Daphne alpina</i>	*	*	*	I	*	*	*	*	*	*	*	*	*
<i>Jurinea consaguinea</i>	*	*	*	*	III	*	*	*	*	*	*	*	*
<i>Inula * aschersoniana</i>	*	*	*	*	II	*	*	*	*	*	*	*	*
<i>Saxifraga juniperifolia</i>	*	*	*	*	*	III	*	*	*	*	*	*	*
<i>Hypochoeris * pelivanovicicii</i>	*	*	*	*	*	*	*	V	*	*	*	*	*
<i>Asperula pirinica</i>	*	*	*	*	*	*	*	V	*	*	*	*	*
<i>Centarea mannagettae</i>	*	*	*	*	*	*	*	IV	*	*	*	*	*
<i>Globularia meridionalis</i>	*	*	*	*	*	*	*	IV	*	*	*	*	*
<i>Allium * minus</i>	*	*	*	*	*	*	*	IV	*	*	*	*	*
<i>Saxifraga * brevifolia</i>	*	*	*	*	*	*	*	*	V	*	*	*	*

RAMONDION NATHALIAE

<i>Carex kitaibeliana</i> (D)	I	II	III	*	*	V	IV	V	*	*	*	*	*
<i>Silene saxifraga</i> agg. (Ch)	II	III	III	I	I	*	II	*	I	V	*	*	*
<i>Hieracium pannosum</i> (Ch)	II	II	*	*	III	*	I	V	*	*	*	*	*
<i>Ramonda nathaliae</i> (Ch)	V	*	III	V	V	*	*	*	*	V	*	*	*
<i>Saxifraga grisebachii</i> (Ch)	III	*	*	III	IV	*	*	*	*	*	*	*	*
<i>Campanula formanekiana</i> (Ch)	*	*	*	V	V	*	*	*	*	*	*	*	*
<i>Saxifraga porophylla</i> (Ch)	I	I	IV	*	*	*	*	*	*	*	*	*	*
<i>Alyssum corymbosum</i> (Ch)	I	*	*	*	I	*	*	*	*	*	*	*	*
<i>Frangula rupestris</i> (D)	I	I	*	III	III	*	*	*	*	*	*	*	*
<i>Draba elongata</i> (D)	II	II	I	*	*	*	*	*	*	*	*	*	*
<i>Campanula versicolor</i> (D)	II	III	*	*	*	*	*	*	*	*	*	*	*
<i>Minuartia verna</i> (Ch)	*	*	*	*	IV	*	V	I	*	*	*	*	*
<i>Achillea ageratifolia</i> agg. (Ch)	*	*	*	*	II	*	II	V	*	*	*	*	*
<i>Potentilla * stojanovii</i> (Ch)	*	*	*	*	*	III	V	I	*	*	*	*	*
<i>Leontopodium * nivale</i> (Ch)	*	*	*	*	*	IV	III	I	*	*	*	*	*
<i>Campanula * pirinica</i> (Ch)	*	*	*	*	*	II	II	II	*	*	*	*	*

ASSOCIATIONS OF THE EDRAIANTHO-ERYSIMION (Ch & D)

<i>Ramonda serbica</i>	*	*	*	*	*	*	*	*	*	*	V	*	*
<i>Alyssum * orientale</i>	*	*	*	*	*	*	*	*	*	*	IV	*	*
<i>Viola grisebachiana</i>	*	*	*	*	*	*	II	II	*	*	*	V	*
<i>Thymus serbicus</i>	*	*	*	*	*	*	*	*	*	*	IV	*	*

EDRAIANTHO-ERYSIMION COMATAE

<i>Carum rigidulum</i> (incl. <i>graecum</i>)	*	*	*	*	III	I	V	*	IV	II	IV	2+-1
<i>Sedum ochroleucum</i>	*	*	*	*	I	*	I	III	*	IV	*	2+-1
<i>Campanula rotundifolia</i>	*	*	*	*	IV	*	II	*	IV	IV	IV	2+
<i>Dianthus petraeus</i>	*	*	*	*	*	*	III	V	IV	V	II	2+-1
<i>Aster alpinus</i> (incl. <i>dolomiticus</i>)	*	*	*	*	*	III	II	II	*	I	*	*
<i>Sesleria rigida</i> (D)	*	*	*	*	*	*	*	IV	V	V	IV	2+-1
<i>Erysimum comatum</i> (Ch)	*	*	*	*	*	*	*	IV	V	IV	IV	2+
<i>Edraianthus graminifolius</i> (Ch)	*	*	*	*	*	*	*	*	V	II	II	2+
<i>Cerastium banaticum</i> (Ch)	*	*	*	*	*	*	*	III	*	III	I	*
<i>Edraianthus serbicus</i> (Ch)	*	*	*	*	*	*	*	*	*	*	II	2+-1

POTENTILLETALIA CAULESCENTIS

Micromeria cristata	IV	II	.	V	III	.	.	IV	.	II	.	.
Seseli rigidulum	IV	.	.	.	.	.	.	I	IV	II	IV	.
Asplenium viride	.	.	III	.	.	I	.	.	III	I	.	2+-1
Potentilla * apennina	.	.	V	.	.	.	.	.	IV	.	.	22-3

ASPLENIETEA TRICHOMANIS

Asplenium ruta-muraria	III	IV	III	V	III	.	.	.	II	IV	IV	2+
Asplenium trichomanes	.	.	I	I	II	.	.	I	IV	IV	II	.
Sedum dasphyllum	.	IV	I	III	III	.	.	II	.	.	.	.
Silene pusilla	.	I	II	.	.	.	.	.	III	I	.	2+-1
Asplenium fissum	.	I	I	.	.	II	.	.	.	.	.	.
Draba aizoides	.	I	.	III	.	.	.	.	.	.	.	.
Cystopteris fragilis	.	.	.	.	.	.	.	.	IV	I	.	.

Localities of tables (Tab. 2):

1. Micromeria-Violetum kosaninii; Horvat et al. (1974), Tab. 140, column 1; Macedonia
2. Saxifrago-Potentilletum speciosae; Horvat et al. (1974), Tab. 140, column 2; Galičica, Bistra, Korab (Macedonia)
3. Saxifrago karadzicensis-Potentilletum apenninae; Horvat et al. (1974), Tab. 140, column 3; Jakupica (Macedonia)
4. Campanuletum formanekianae; Horvat et al. (1974), Tab. 140, column 4; Nidža (Macedonia)
5. Campanulo formanekianae-Ramondietum nathaliae; Quézel (1967), Tab. 6; Vermion (Greece)
6. Leontopodio-Potentilletum stojanovii; Simon (1958), Tab. I; Pirin (Bulgaria)
7. Leontopodio-Potentilletum stojanovii; Tab. 1 in this study, relevés 10-16; Pirin
8. Hieracio pannosi-Caricetum kitaibelianae; Tab. 1 in this study, relevés 1-9; Pirin
9. Saxifragetum brevifoliae; Horvat et al. (1974), Tab. 140, column 6; eastern Serbia
10. Erysimo-Ramondietum nathaliae; Jovanović-Dunjić (1953), Tab. 1; Suva Planina (Serbia)
11. Ceteracho-Ramondietum serbicae; Jovanović-Dunjić (1953), Tab. 2; Rtanj (Serbia)
12. Saxifrago aizoi-Violetum grisebachianae; Jovanović-Dunjić (1956), Tab. 12; Rtanj (Serbia)
13. Potentilla apennina-Saxifraga aizoon-Ges.; Jovanović-Dunjić (1955); p. 88; Suva Planina (Serbia)

Floristically and synecologically analogous community was reported from the Bucegi Mts. by Domin (1983). This community grows on gentle slopes covered with water-soaked soils on limestone. It is frequented by dominant *Silene pusilla* and *Doronicum carpaticum*; further *Saxifraga paniculata*, *S. adscendens*, *S. androsacea*, *Viola biflora* and *Mysotis alpestris* are also found. The community is also rich in mosses.

Syntaxonomy of the Asplenetea trichomanis communities

The plant communities in rock fissures and crevices of the Balkans ever enjoyed much interest of vegetation systematists. Major motivations for this interest are the high number of endemic and relict species found in the communities as well as diversity of types encountered over the varied high-mountain landscape of the Balkan Peninsula. The syntaxonomy of the *Asplenetea trichomanis* in the Balkan Peninsula is based mainly on works of Horvat (1931, 1934, 1936, 1937, 1960) who described many types and several high-ranked syntaxa from Yugoslavia (Macedonia, Serbia, Croatia). Quézel (1964, 1967) described rock-fissure communities from

Tab. 3 - *Silene pusilla*-*Saxifraga oppositifolia* community.

No of relevé	12
Exposition	WW SS WW
Slope °	89 00
Sampled area m²	94
Cover of herb layer %	12 55
Cover of moss layer %	<3 55

ASPLENIETEA TRICHOMANIS

<i>Silene pusilla</i>	56
<i>Campanula</i> * <i>pirinica</i>	55
<i>Asplenium fissum</i>	23
<i>Encalypta streptocarpa</i>	22
<i>Euphrasia salisburgensis</i>	11
<i>Thymus cherlerioides</i>	.2

THLASPIETEA ROTUNDIFOLII

<i>Galium stojanovii</i>	36
<i>Saxifraga oppositifolia</i>	23
<i>Veronica</i> * <i>kellereri</i>	23
<i>Viola grisebachiana</i>	23
<i>Alyssum</i> * <i>pirinicum</i>	22
<i>Armeria</i> * <i>alpina</i>	22
<i>Myosotis alpestris</i>	22
<i>Thlaspi bellidifolium</i>	22
<i>Papaver</i> * <i>degenii</i>	21
<i>Doronicum columnae</i>	6.
<i>Saxifraga</i> * <i>discolor</i>	2.
<i>Saxifraga</i> * <i>pirinica</i>	3.
<i>Arabis caucasica</i>	.2
<i>Saxifraga luteoviridis</i>	.1

FESTUCO-SESLERIETEA

<i>Cerastium</i> * <i>lanatum</i>	22
<i>Poa alpina</i>	22
<i>Pedicularis verticillata</i>	.1
<i>Saxifraga ferdinandi-coburgi</i>	.1

SALICETEA HERBACEAE

<i>Poa pirinica</i>	22
<i>Draba scardica</i>	.2
<i>Omalotheca supina</i>	.3
<i>Sedum atratum</i>	.2

OTHER PHANEROGAMS

<i>Hieracium</i> sp.	.2
<i>Taraxacum</i> sp.	.2

CRYPTOGAMS

<i>Leskea polycarpa</i>	37
<i>Hymenostylium recurvirostre</i>	35

<i>Tortella tortuosa</i>	33
<i>Bryum caespiticiu</i>	22
<i>Collema</i> sp.	22
<i>Toninia</i> sp.	22
<i>Tortula sinensis</i>	22
<i>Bryum elegans</i>	3.
<i>Protoblastenia terricola</i>	2.
<i>Psora decipiens</i>	2.
<i>Hypnum cupressiforme</i>	.2
<i>Leptogium sinuatum</i>	.2
<i>Plagiochila porelloides</i>	.2

Greece. Many papers deal with the *Asplenietea trichomanis* in Rumania (eg. Borhidi 1958, Schneider-Binder 1968, 1969, 1972, 1975, 1980, Schneider-Binder & Voik 1977, Täuber 1985). In Bulgaria Pawlowski et al. (1937) and Simon (1958) brought descriptions of same new associations of the *Asplenietea trichomanis*.

The communities typical of lime-rich substrata (limestone, marble) from Macedonia and Bulgaria were classified within the *Ramondion nathaliae* (cf. Horvat 1936, Jovanović-Dunjić 1953, 1955, 1956, Simon 1958, Blečić & Tatić 1960).

Ramondion nathaliae suggested Horvat (1935, 1936) for south-Macedonian mountain ranges. The descriptions are, however, rather unclear. No diagnostic species are given and the associations supposed to be included within the *Ramondion nathaliae* are also not listed. Horvat (1936) listed only a few species, such as *Ramonda nathaliae*, *Saxifraga scardica*, *S. marginata*, *S. grisebachii*, *Potentilla apennina*, *Campanula formanekiana*, *Micromeria cristata* and some others, as dominants. The same name was used by Jovanović-Dunjić (1953, 1955, 1956) and Blečić & Tatić (1960) for a group of east-Serbian communities. Neither in these papers the validation of the alliance was performed. *Ramondion nathaliae* was validated by Simon (1958) by listing character species of the alliance (see Tab. I in Simon 1958). He assigned the *Leontopodio* - *Potentilletum stojanovii* into the *Ramondion nathaliae* sensu Horvat (1935), thus interpreted the alliance as that comprising the fissure plant communities occurring in southern Macedonia (Yugoslavia), Bulgaria and most probably also some mountains of northern Greece and Albania. Quézel (1967) listed *Minuartia verna*, *Saxifraga grisebachii* (also near Bansko; Kuzmanov 1970), *Micromeria cristata* and *Achillea ageratifolia* subsp. *aizoon* as members of the diagnostic species group for the *Ramondion nathaliae*. Horvat et al. (1974) added also *Hieracium pannosum*, *Campanula versicolor*, *Alyssum corymbosum* and *Cerastium banaticum* to the diagnostic species of the alliance.

According to our opinion the use of the *Ramondion nathaliae* for the east-Serbian communities is incorrect because of the floristic differences between the Macedonian and Serbian plant communities of the *Asplenietea trichomanis* (Tab. 2). Therefore we describe a new alliance for the east-Serbian communities, the *Edriantho graminifolii* - *Erysimum comatae* all. nova (nomenclatural type: *Ceteracho* - *Ramondietum serbicae* Jovanović-Dunjić 1952). The diagnostic taxa of the alliance comprise *Erysimum comatum* (char.), *Edraianthus graminifolius* (char.), *E. serbicus* (char.), *Cerastium banaticum* (reg. char.), *Sesleria rigida* (dif.), *Sedum ochroleucum* (char.) *Ramonda serbica* (char.), *Alyssum saxatile* subsp. *orientale* (char.), *Viola grisebachiana* (reg. char.) and *Thymus serbicus* (char.).

It should be noted, however, that the Bulgarian communities (*Leontopodio - Potentilletum stojanovii* and *Hieracio pannosi-Caricetum*) are differing from the Yugoslavian Macedonian group by the endemic Bulgarian (and Pirin) species, and at the same time show some floristic relations to the *Edraiantho-Erysimion comatae* by common occurrence of species such as *Aster alpinus*, *Carum rigidulum* agg., *Campanula rotundifolia*, *Dianthus petraeus*, *Sedum ochroleucum* and the like.

According to the syntaxonomic revision summarized in Tab. 2 we suggest the following classification of *Potentilletalia caulescentis* in southeastern Balkan Peninsula:

Asplenietea trichomanis (Br. - Bl. in Meier et Br. - Bl. 1934) Oberd. 1977

Potentilletalia caulescentis Br. - Bl. 1926

Ramondion nathaliae Horvat ex Simon 1958

1. *Micromerio-Violetum kosaninii* Horvat ex Horvat et al. 1974
2. *Saxifrago-Potentilletum speciosae* Horvat et al. 1974 (syn. *Potentilla speciosa-Minuertia graminifolia*-Ass. Horvat 1937)
3. *Saxifrago karadzicensis-Potentilletum apenninae* Horvat ex Horvat et al. 1974
4. *Campanulo-Inuletum candidae* Horvat 1949
5. *Campanuletum formanekianae* Horvat 1938
6. *Campanulo formanekianae-Ramondietum nathaliae* Quézel 1967
7. *Achilleo-Aubrietetum gracilis* Horvat 1936
8. *Leontopodio-Potentilletum stojanovii* Simon 1958
9. *Hieracio pannosi-Caricetum kitaibelianae* Mucina et al. 1990

Edraiantho graminifolii-Erysimion comatae Mucina et al. 1990

10. *Erysimio-Ramondietum nathaliae* Jovanović-Dunjić 1952
11. *Saxifragetum brevifoliae* Blečić et Tatić 1960
12. *Ceteracho-Ramondietum serbicae* Jovanović-Dunjić 1952
13. *Saxifrago aizoi-Violetum grisebachianae* Jovanović-Dunjić ex Mucina et al. hoc loco
(syn. As. *Saxifraga Aizoon-Viola Grisebachiana* prov.; Jovanović-Dunjić 1956)
nomenclatural type: Tab. 12, relevé 4 in Jovanović-Dunjić (1956, p. 34), lectotypus
14. *Potentilla appennina-Saxifraga aizoon* community (Jovanović-Dunjić 1955)

3.2. Plant Communities on Marble Scree

High altitudes, both in the subalpine (low-situated sites in glacial valleys) and alpine (slopes of high-elevated glacial circles) belts in the marble part of the Northern Pirin Planina Mts. are rich in scree habitats resembling those in the Alps (Zollitsch 1966). Three associations, including the *Papaveri degenii-Armerietum*

alpinae, *Veronico kellereri-Silenetum prostratae* (belonging to a new alliance, the *Veronico-Papaverion degenii*), and the *Bromo lacmonices-Geranium macrorrhizi* (the *Silenion marginatae*) are described in the sequel.

Papaveri degenii-Armerietum alpinae ass. nova

Nomenclatural type: Tab. 4, relevé 12, hoc loco

The *Papaveri degenii-Armerietum alpinae* is a pioneer community of low-grown herbs, grasses and mosses growing on crystalline limestone screes in the alpine belt of the Pirin Planina Mts.

The stands populate foothill screes and slopes of moraines at altitudes between 2200 to 2700 m. The slope of the screes ranks between 25-45° and only exceptionally are more gentle (5-10°); aspect of the slopes is prevalingly north and northeastern, to a lesser extent western or southwestern. The substratum is formed by rocks having 10 to 20 cm in diameter and intermingled with gravel (3 to 5 cm in Ø). Fine-grained soil particles occur in varying quantities. Most of the habitats are well-supplied by water which comes either directly from rainfall or, mainly, from thawing snow and firn patches. Large water streams emerging in spring usually give rise to erosion dells in the scree cones, and aid, together with large boulders, differentiation of the scree into variety of microhabitats. This reflects also in high species richness of the community.

The stands, sometimes more than 50 m² large, and with total cover ranging from 25 to 75%, are dominated by chasmophytes. The stands are bistratal; the lower herb sublayer (1 to 5 cm) is formed by dwarf *Arenaria biflora*, *Silene pusilla*, *Cerastium alpinum* subsp. *lanatum*, *Galium stojanovii*, *Saxifraga oppositifolia* and rosettes of several *Saxifraga* species. The higher herb sublayer (5 to 15, max. 25 cm high) is formed by the dominants of the community, such as *Armeria pocutica* subsp. *alpina*, *Doronicum columnae*, *Papaver degenii*, *Myosotis alpestris*, and *Veronica saturejoides* subsp. *kellereri*. The moss layer (1 to 4 cm) is also well-developed, mainly in wetter microhabitats, where it may attain 30 to 60%. The most frequent cryptogams include *Ditrichum flexicaule*, *Hymenostylium recurvirostre*, *Leskea polycarpa*, *Tortella tortuosa*, *Preissia quadrata* and *Tortula sinensis*.

Syndynamically the *Papaveri-Armerietum* is seen as arrested (blocked) successional stage (sensu Moravec 1969) of a pioneer character. In dried and more insolated habitats, after the screes has been partly consolidated by fine-grained soil, the stands become impoverished of typical scree species (*Veronica saturejoides* subsp. *kellereri*, *Doronicum columnae*, *Saxifraga adscendens* subsp. *discolor*) while tussock-forming grasses and sedges, such as *Sesleria coerulans*, *Festuca riloensis* (only rarely), *Carex rupestris*, *Carex laevis* (frequently) take over. The further succession proceeds in direction to the *Anthyllo-Seslerion klasterskyi* Simon 1958 (*Festuco-Seslerietea* Barbero et Bonin 1969), most probably towards the *Carici rupestris-Seslerietum klasterskyi* Simon 1958 described from the Vikhren Mt. The latter community forms a transition between the *Veronico-Papaverion degenii* and *Anthyllo-Seslerion klasterskyi*. In wetter, shady and gentle-sloped habitats the

Tab. 4 - The communities of the Veronico-Papaverion degenii.

No. of relevé	11111111112222 222222	C1	C2
	12345678901234567890123 456789	%	%
Exposition	NN N NN EE N NN W EE EE NE NNNN NN N NNNSSNN SSS S ENNNEEENEENEENWNEEEWEEEN EEEEE		
Slope °	3143313133433 342334441 444444 00500005050505555505005		
Sampled area m²	1 1 253232 312233134 486553 60885331058586001450650 803006		
Cover of herb layer %	4625525353325446433531 243432 00005505055050000000505 000050		
Cover of moss layer %	365<6312< 1<5 <1< << << < < 000100505-55555505--15- 15-1-1		
PAPAVERI-ARMERIETUM ALPINAE			
Saxifraga * discolor (Ch)	2.32..25533333233232.3	83	0
Papaver * degenii (Ch)	.2352..255225...2.55355	70	17
Viola grisebachiana (Ch)	22.22..2222.2.2523522.	70	0
Saxifraga androsacea (Ch)	775775552.....2.....	43	0
Ditrichum flexicaule (D)	23..3552.2322633233...	70	0
Leskea polycarpa (D)	542.62.3..54.5..3...2..	48	0
Sedum atratum (D)	.....2222.2222.....21.	43	0
Pedicularis verticillata (D)	.....122.....22.2..21.	35	0
Saxifraga exarata (D)	....33.....2.....35.2.	26	0
Draba scardica (D)	..2.....2.1..2..2	22	0
Peltigera rufescens (D)	.....2.....23.2.....1.	22	0
Solorina bispora (D)	..2.22.....2.....2..	22	0
D-TYPICUM			
Arenaria biflora	33232.2222.2255232.....	70	67
Omalotheca supina	22...2222.23.52535.....	57	0
Hymenostylium recurvirostre	67..7343..53...22.....	39	17
Preissia quadrata	22...3.2.22..32.2.....	39	0
Mnium stellare	24..22..2..2.32.....	35	0
Salix reticulata	23.....5.....22..2.....	26	0
Primula minima	..2.53.....3..2.....	22	0
Carex parviflora	..2.7.....5.....	13	0
Drepanocladus aduncus	..8..7.....	9	0
Plantago atrata	..2.....3.....	9	0
D-FESTUCETOSUM RILOENSIS			
Festuca riloensis	.....3...5253.....	22	0
Alyssum * pirinicum (D)	.....3553..2.2.5	17	50
Pedicularis orthantha	.....2.2.2.2.....	13	17
Dianthus microlepis	.....2..2..4..2..	13	17
VERONICO-SILENETUM PROSTRATAE			
Silene * prostrata (Ch)	.....2. 276776	4	100
Senecio rupestris (D)	.....223.22	0	83
Festuca valida (D)	.....3. 5426.3	4	83
Linum capitatum (D)	.....2.522	0	67
VERONICO-PAPAVERION DEGENII			
Poa pirinica	522353332553255355..33..	87	50
Veronica * kellereri	22...2.33523325532222. 363655	74	100
Galium stojanovii	3...2...2322335355.33. 2.2322	61	83
Erigeron vichrenensis	.....2..2222.....	22	0
Arabis ferdinandi-coburgi	.....2.2.....4.3	9	33
THLASPIETEA ROTUNDIFOLII			
Doronicum columnae	355.35775555577352.353. 55523.	87	83
Armeria * alpina	23232.2253.555327755755 22.2..	91	50
Myosotis alpestris	23232525755553555523.25 5...4.	96	50

<i>Saxifraga oppositifolia</i>	235232232225523.23535.5	2....	91	17
<i>Arabis caucasica</i>	253222.2235222.2.....	3....	61	17
<i>Saxifraga luteoviridis</i>	2.....1.1222.2222.2...	...2..	48	17
<i>Thlaspi bellidifolium</i>	.....232...55.33.2	...232	35	50
<i>Tortula sinensis</i>	2...62.5....2...2....	22....	26	33
<i>Myosotis suaveolens</i>	.....2...2.3...	...42.3	13	50
<i>Silene acaulis</i>	.....3...3...5...2	.....	17	0
<i>Geum reptans</i>	.....5...52.....	.....	13	0
<i>Veronica alpina</i>	.....5...2.....	.....	9	0
<i>Scrophularia * laciniata</i>	.....5...2.....	.....2	0	17

FESTUCO-SESLERIETEA

<i>Poa alpina</i>	3..2..2.3.2.3..2.235355	5....	57	17
<i>Sesleria coerulans</i>	54.....23.2.5532.2.2	2..422	48	67
<i>Cerastium * lanatum</i>	..22.....22..32...55.23	...2..	43	17
<i>Helianthemum * tomentosum</i>	3.....25.....	...5.2	4	33
<i>Botrychium lunaria</i>	.....25.....2	.....	13	0
<i>Saxifraga ferdinandi-coburgi</i>	.....2...22.....	.....	13	0
<i>Acinos alpinus</i>	.....3.....	.....	0	17
<i>Silene * graefferi</i>	.....5.....	...2..	4	17

ASPLENIETEA TRICHOMANIS

<i>Silene pusilla</i>	23.2..22.233225323...2	.....	65	0
<i>Tortella tortuosa</i>	2.....2222.2.32.....	..2.2.2	35	50
<i>Euphrasia salisburgensis</i>	.....1.....2	...2.2	9	33
<i>Cystopteris regia</i>	22.....2...3.....	.....	17	0
<i>Thymus cherlerioides</i>	.....2.....2	.....	9	0
<i>Carex kitaibeliana</i>	.....3.3.....	.....	9	0
<i>Potentilla * stojanovii</i>	.....1.....	.....	4	0
<i>Campanula * pirinica</i>	.....2.3.....	.....	0	33
<i>Helianthemum canum</i>	.....2.....	.....	0	17
<i>Asperula suberosa</i>	.....2.....	.....	0	17
<i>Carum rigidulum agg.</i>	.....2.....	.....	0	17

SALICETEA HERBACEAE

<i>Ligusticum mutellina</i>	.....23.....	.....	0	33
<i>Bartsia alpina</i>	.2.....2.....	.....	9	0
<i>Gentiana verna</i>	.....2.....	.....	4	0
<i>Sagina saginoides</i>	.....3.....	.....	4	0
<i>Saxifraga heucherifolia</i>	.3.....	.....	4	0
<i>Potentilla crantzii</i>	.....2.....	.....	4	0
<i>Anthelia juratzkana</i>	.....2.....	.....	4	0
<i>Artemisia eriantha</i>	.....2.....	.....	4	0
<i>Polygonum viviparum</i>	.2.....	.....	4	0
<i>Primula halleri</i>	.....1.....	.....	4	0
<i>Soldanella pusilla</i>	.....5.....	.....	4	0

OTHER PHANEROGAMS

<i>Taraxacum nigricans agg.</i>	55232.235332.3255522232	55223.	91	83
<i>Hieracium Bg24</i>	.....22.....	.....	0	33
<i>Juniperus * nana</i>	.....1.....	.....	0	17
<i>Knautia sp.</i>	.....2.....	.....	0	17
<i>Cerastium sp.</i>	.....2.....	.....	4	0

OTHER CRYPTOGRAMS

<i>Bryum caespitium</i>	...2.2.5.....2	.....	17	0
<i>Brachythecium velutinum</i>	.....22..22.....2	.....	22	0
<i>Bryum elegans</i>	2.....3.....2	.....	13	0
<i>Collema sp.</i>	2.....2.....2	.....	13	0
<i>Encalypta streptocarpa</i>	2.....3.....2	.....	13	0
<i>Cladonia sp.</i>	.2.....3.....	.....	9	0
<i>Toninia candida</i>	.22.....	.....	13	0
<i>Anomodon viticulosus</i>	.....6.....	.....	4	0
<i>Bryum sp.</i>	.....3.....	.....	4	0
<i>Catopryrenium cinereum</i>	.....2.....	.....	4	0
<i>Cirriophyllum cirrosum</i>	.....2.....	.....	4	0
<i>Cladonia pocillum</i>	.....2.....	.....	4	0
<i>Collema tenax</i>	.....2.....	.....	4	0
<i>Hypnum cupressiforme</i>	.....3.....	.....	4	0
<i>Leptogium lichenoides</i>	2.....	.....	4	0
<i>Plerospora hookeri</i>	.....2.....	.....	4	0
<i>Pseudoleskea nervosa</i>	.....5.....	.....	4	0
<i>Tortula intermedia</i>	.....2.....	.....	4	0
<i>Timmia austriaca</i>	.6.....	.....	4	0
<i>Jungermania leiantha</i>	.2.....	.....	4	0

Notes: C1 - constancy of *Papaveri-Armerietum*; C2 - constancy of *Veronico-Silenetum prostratae*; for other abbreviations see Tab. 1.

development might proceed towards the *Salicetea herbaceae*, as also shown by the occurrence of many snow-patch species in the subassociation *typicum*.

The *Papaveri - Armerietum* is a rather common feature of scree slopes of all of the glacial circles in the marble part of the Northern Pirin Planina Mts. It is supposed to be located also at the Sinanitsa Mt.

Papaver degenii, *Saxifraga adscendens* subsp. *discolor*, *S. androsacea* and *Viola grisebachiana* are the character taxa of the association, while *Ditrichum flexicaule*, *Leskea polycarpa*, *Sedum atratum*, *Solorina bispora*, *Pedicularis verticillata*, *Saxifraga exarata* subsp. *pirinica*, *Draba scardica* and *Peltigera rufescens* differentiate the *Papaveri-Armerietum* well from the *Veronico-Silenetum prostratae* (see below).

In relation to soil moisture, the degree of scree stabilization and granulometric composition of the soil, the *Papaveri-Armerietum* is differentiated into a series of synecologically and floristically well-discernible units including the subassociation *typicum* (with typical variant and variant with *Saxifraga androsacea*) and the *festucetosum riloensis*.

Papaveri degenii-Armerietum alpinae typicum subass. nova

Nomenclatural type: identical with that of the association.

The soil supporting this community is skeletal, rich in boulders and gravel, and with a varying amount of fine-grained material. The slope of the sites is frequently 30 to 45°. among aspects north is the prevailing one, while east and west occur less frequently. The community occurs in extensive stands (up to 100 m²); they are 10 to 25 cm high and poor in mosses. The differential species of the subassociation are *Arenaria biflora*, *Omalotheca supina*, *Salix reticulata*, *Primula minima*, *Carex parviflora*, *Plantago atrata*, *Preissia quadrata*, *Hymenostylium recurvirostre*, *Mnium stellare* and *Drepanocladus aduncus*.

There are two synecologically well-interpretable variants within the typical subassociation such as the variant with *Saxifraga androsacea* and typical variant. The stands of the former one populate the wettest habitats soaked with percolating water coming from thawing snow patches in upper positions of the scree cones found under steep rocky walls in mouths of rocky dells and gorges. The fine-grained to gravelly, largely stabilized screes (10 to 30° steep) face north or northeast. The stands are carpet-like, low-grown (5 to 10 cm) and small-sized. At sites with gentle slope these habitats resemble snow patches. The community is characterized by dominance of *Saxifraga androsacea*, which seems to occur more frequently on silicate bedrock in other mountain ranges of Europe (eg. Domin 1930). The high cover values of several moss species such as *Drepanocladus aduncus*, *Hymenostylium recurvirostre*, *Leskea polycarpa* and *Tortula sinensis* are also of diagnostic value for the variant.

Along a complex ecocline (from wet habitats with fine-grained soil towards sunny and dried habitats with coarse-grained screes) the typical variant occupies an intermediate position between the *Saxifraga androsacea* variant and the subassociation *festucetosum riloensis*.

Papaveri degenii-Armerietum alpinae festucetosum riloensis subass. nova
Nomenclatural type: Tab. 4, relevé 21 hoc loco

The subassociation is limited to well-insolated habitats enjoying all-day-long sunshine. These are found on convex scree cones and ridges of moraines. The screes are gravelly, with a share of small rocks; the amount of fine-grained material and boulder is very varying. The slopes housing stands of the community usually face south-west to east-north or east aspects. The community occurs frequently at altitudes between 2600 to 2700 m. The stands are rather extensive and only poorly covered (35% on the average). Mosses are rare. The differential taxa of the subassociation include *Alyssum cuneifolium* subsp. *pirinicum*, *Festuca riloensis*, *Dianthus microlepis* and *Pedicularis orthantha*. The latter species occurs more frequently on granitic bedrock especially in central and southern parts of the Pirin Planina Mts. or in other Bulgarian mountain ranges, eg. Rila Planina Mts. where it is considered a character species of the *Carici curvulae-Festucetum riloensis* Horvat et al. 1937 (*Seslerion comosae* Horvat 1935, *Caricetea curvulae* Br. - Bl. 1948).

In comparison to other *Veronico-Papaverion* communities, the *festucetosum riloensis* is characterized by higher frequency of occurrence of *Poa alpina* and *Cerastium alpinum* subsp. *lanatum*.

Veronico kellereri-Silenetum prostratae ass. nova
Nomenclatural type: Tab. 4, relevé 27, hoc loco

The *Veronico - Silenetum prostratae* is a pioneer community of herbs populating bouldery marble screes in the alpine belt of the Pirin Planina Mts.

The community was recorded from the Golemiya Kazan Circle on moving screes found on south and southeast-facing steep slopes (40 to 45°). The screes were built of marble skeleton (5 to 30 cm in Ø) and admixed boulders as large as 1 m in diameter. A small amount of fine-grained eroded rocky material flushed on the bottoms of deep cracks among the boulders is also found. The screes are insolated during the most of the day, thus the sites are relatively warm and dry.

The stands of the community are 50 to 100 m² large, with rather loose canopy (cover 20 to 40% of a plot) and are strikingly stratified. The upper-most sublayer (up to 30 cm) is formed by the dominant *Silene vulgaris* subsp. *prostrata* and accompanied by *Doronicum columnae*. The middle herb sublayer (10 to 20 cm) is the species-richest stratum of the stands. *Veronica saturejoides* subsp. *kellereri*, *Senecio rupestris*, *Armeria pocutica* subsp. *alpina*, *Linum capitatum*, *Myosotis alpestris*, *M. suaveolens* and *Arabis ferdinandi-coburgi* are found in it. The lower herb sublayer (up to 5 cm) is frequented by dwarf-grown species such as *Galium stojanovii*, *Arabis biflora* and *Euphrasia salisburgensis*. Due to extreme microclimatic conditions and the overall dryness of its sites the community is poor in mosses.

Silene vulgaris subsp. *prostrata* occurs in high mountains on calcareous screes in many European countries, where it is considered a typical scree element (Hadač et al. 1969, Duvigneaud et al. 1970, Richard 1971, Valachovič 1989).

The dominant taxon, together with *Festuca valida*, *Senecio rupestris* and *Linum capitatum* form the character taxon combination of the *Veronico-Silenetum prostratae*. A synecologically analogous community of lower altitudes is the *Bromo lacmonices* - *Geranietum macrorrhizi* (see below). The following relevé is a transition between these two units:

Kamenititsa Tsirkus, altitude 2200 m, aspect E, slope 30°, sampled area 30 m², cover of herb layer 40%; August 13, 1984.

Bromus cappadocicus subsp. *lacmonices* 1, *Scrophularia heterophylla* subsp. *laciniata* 2a, *Senecio rupestris* 1, *Silene vulgaris* subsp. *prostrata* 1, *Thalictrum minus* subsp. *olympicum* 3, *Arabis caucasica* 1, *Doronicum columnae* +, *Festuca valida* +, *Mysotis alpestris* +, *Veronica saturojoides* subsp. *kellereri* +, *Sesleria coerulans* 2a, *Poa alpina* 2m, *Acinos alpinus* 1, *Cirsium appendiculatum* 1, *Hieracium grandiflorum* 1, *Onobrychis montana* subsp. *scardica* +, *Dianthus scardicus* +, *Phleum montanum* +, *Euphorbia cyparissias* +, *E. amygdaloides* +, *Galium anisophyllum* agg. +, *Asplenium fissum* +, *Kernera saxatilis* +, *Hieracium pannosum* r. *Scorzonera rosea* +, *Daphne oleoides* +, *Taraxacum* sp. +.

Bromo lacmonices-*Geranietum macrorrhizi* ass. nova

Nomenclatural type: Tab. 5, relevé 3 hoc loco

The community populates moving or slightly stabilized screes on east- and south-facing slopes (15 to 40°) that occur mainly in the belt of *Pinus leucodermis* (at altitudes between 1800 to 2000 m). The skeleton building the screes is the marble stones (20 to 30 cm in diameter); also large boulders (up to 1 m in diameter) are present. At lower altitudes, also an admixture of granite stones was observed. Gravel and fine-grained material is scarce and it is concentrated on bottoms of the fissures among the scree rocks.

The stands of the community are from 20 to 100 m² in extent. Usually they are covering the scree in broad belts following the main axis of the scree. The total coverage is dependent on the cover of *Geranium macrorrhizum*, a chasmophyte broadly tolerating the range of soil reaction. Other species occur sparsely. Some epiterrestrial mosses occur among the boulders. More frequently occur epilithic lichens and mosses.

The group of character taxa consists of *Geranium macrorrhizum*, *Bromus cappadocicus* subsp. *lacmonices* and *Moehringia pendula*. The classification of the *Bromo-Geranietum macrorrhizi* is problematic because of the broad habitat requirements of the dominant species (Boşcaiu 1971, Sanda et al. 1977). *Geranium macrorrhizum* is distributed (in Europe) in the Apennines, Southern Alps, Eastern and Southern Carpathians and other Balkan mountains. Most often it is limited to calcareous screes. In southern Greece (the Parnassos Mts.) it is a dominant species in the *Senecioni thapsiformi* - *Geranietum macrorrhizi* (Quézel 1964), a vicariant unit to the *Bromo-Geranietum macrorrhizi*, occurring in analogous habitats and in the same altitudinal belt. Quézel (l.c.) classified the community within the *Silenion caesia* Quézel 1967 (*Drypetea spinosae* Quézel 1964). However, both associations share only one species - *Geranium macrorrhizum*. In Southern Alps, *Geranium macrorrhizum* occurs in the *Moehringio-Gymnocarpium robertianum* (*Petasition paradoxum* Zollitsch 1966, *Drabetalia hoppeanae* Zollitsch 1966, *Thlaspietea rotundi-*

Tab. 5 - Bromo-Geranium macrorrhizi (Silenion marginatae).

No. of relevé	12345	C
Exposition	EE S SSSSS EEEE	%
Slope °	32334 50050	
Sampled area m ²	34572 50000	
Cover of herb layer %	< < 555--	

BROMO-GERANIETUM MACRORRHIZI		
Geranium macrorrhizum (Ch)	77785	100
Bromus * lacmonices (Ch)	223.2	80
Moehringia pendula (Ch)	322.4	80
THLASPIETEA ROTUNDIFOLII		
Thalictrum * olympicum	22233	100
Lamium garganicum	2.22.	60
Senecio rupestris	22...	40
Heracleum * verticillatum	..2..	20
Scrophularia * laciniata	....2	20
OTHER PHANEROGAMS		
Teucrium chamaedrys	23232	100
Campanula velebatica	22...	60
Festuca sp.	..2.32	60
Melica ciliata	323..	60
Asyneuma canescens	..2.2.	40
Cuscuta sp.	..22..	40
Euphorbia cyparissias	..22..	40
Urtica dioica	32...	40
Bupleurum sibthorpiatum	...2.	20
Cirsium appendiculatum	..2...	20
Euphorbia amygdaloides	..2..	20
Galium album	..2..	20
Kernera saxatilis	..2...	20
CRYPTOGAMS		
Tortula intermedia	253..	60
Orthotrichum cupulatum	..22..	40
Tortella tortuosa	23...	40
Campanula rapunculoides	..3..	20
Homalothecium philippeanum	3....	20
Schistidium apocarpum	3....	20
Solorina bispora	..2...	20

Notes: Ch - character species.

folii). Boşcaiu (1971) described the *Geranium macrorrhizi* from limesone screes with a granite admixture from the Cernei Mts. (the Southern Carpathians). The altitudinal range of the latter community is, however, shifted more to lower altitudes (between 380 to 1400 m) which suggests a classification of the *Geranium macrorrhizi* Boşcaiu 1971 into the *Peltarion alliaceae* Horvatić 1957 (*Thlaspietea rotundifolii*). Only 5 species are common both to the *Geranium macrorrhizi* and *Bromo-Geranium macrorrhizi* (besides the aponymous species, also *Moehringia pendula*, *Melica ciliata*, *Senecio rupestris* and *Urtica dioica*). Blečić (1958) described the *Corydalo-Geranium macrorrhizi* from Montenegro (the Piva Valley in the

Durmitor Mts.), but only *Melica ciliata* and *Geranium macrorrhizum* are shared by the compared communities.

Syntaxonomy of the *Thlaspietea rotundifolii* communities

The discussed communities apparently belong to 2 alliances having their distributional optima in the alpine and subalpine belts, respectively. The *Bromo lacmonices* - *Geranietum* belongs to the *Silenion marginatae* Lakušić 1970 described for the calcareous-scrree communities of the southern Dinarides by Lakušić (1970) and Lakušić et al. (1982) as suggested by lists of diagnostic species. The *Silenion marginatae* includes also another scrree community described from the Pirin Planina Mts. - the *Kenthranthetum kellereri* (Velchev & Vasiliev 1970). This community was reported from the altitudes between 1700 and 1900 m at one locality below the Duninoto Kuche Mt. It is similar to the *Bromo-Geranietum macrorrhizi* by the occurrence of *Teucrium chamaedrys*, *Lamium garganicum*, *Heracleum sphondylium* subsp. *verticillatum* and *Scrophularia heterophylla* subsp. *laciniata*. The dominant and character species of the community is *Kentranthus kellereri*, a Bulgarian endemic plant.

The *Silenion marginatae* is probably a geographic vicariant unit to the *Peltarion alliaceae* distributed in the northern Dinarides and Southern Carpathians (see also above).

The alpine scrree communities show a great degree of resemblance and should be classified within one upper-ranked unit, the *Veronico-Papaverion degenii* all. nova hoc loco (nomenclatural type: *Papaveri degenii-Armerietum alpinae* Mucina et al. 1990). The character taxa of the *Veronico-Papaverion degenii* comprise *Veronica saturejoides* subsp. *kellereri*, *Poa pirinica*, *Galium stojanovii*, *Alyssum cuneifolium* subsp. *pirinicum*, *Erigeron vichrenensis* and *Arabis ferdinandi-coburgi* as well as the character species of the *Papaveri-Armerietum* and *Veronico-Silenetum* (see Tab. 4). This alliance, endemic to Bulgarian mountains (Pirin, probably also Rila and Slavyanka) is a vicariant to the *Saxifragion prenjae* and *Bunion alpini* described by Lakušić (1970) from the Dinarides. The synoptic table of the Dinaride scrree communities (Lakušić 1970: Tab. 10a) supports the separate syntaxonomic position of the *Veronico-Papaverion degenii*. The discussed units are floristically different as they contain many endemic species characteristic of respective distribution areas of the alliances. The *Bunion alpini*, *Saxifragion prenjae*, *Silenion marginatae* and *Veronico-Papaverion degenii* belong to the *Arabidetalia alpinae-flavescentis* Lakušić 1970 (*Thlaspietea rotundifolii*) which is a geographic vicariant to the *Thlaspietalia rotundifolii* of the Alpic-Carpathian Mountain System.

3.3. Plant Communities of Snow-bed Vegetation

The snow-patch (snow-bed) vegetation was studied both on granites, schists and marbles in the central and northernmost parts of the Northern Pirin Planina Mts. Two associations belonging to the *Salicion herbaceae*, such as the *Soldanello*

pusillae-Plantaginietum gentianoidis and *Omalotheco - Alopecuretum gerardii* were described from siliceous bedrocks. The *Gentiano-Plantaginietum atratae* and *Bartsio-Salicetum reticulatae* were found on calcium-rich bedrock; these latter belong to the *Salicion retuso-reticulatae*.

Soldanello *pusillae-Plantaginietum gentianoidis* Boşcaiu 1971

Nomenclatural type: Boşcaiu (1971; Tab. 12, relevé 3), lectotypus

The *Soldanello-Plantaginietum gentianoidis* is a snow-patch plant community supported by siliceous bedrocks. It was noted in the southern part of the Northern Pirin Planina Mts. in the Smirnenski and Belemeto Tsirkus. The habitats of the community are found in concave relief forms; these are shallow depressions hidden among large boulders, as a rule. The snow cover persists longer than in habitats of the *Omalotheco-Alopecuretum gerardii*.

The shallow alpine tangel soils, rich in fine-grained soil material are derived from granite. The soil has higher moisture retention than that supporting the *Omalotheco-Alopecuretum gerardii*. This is indicated also by the occurrence of *Nardus stricta* and *Cerastium cerastoides* as well as high cover values of *Arenaria biflora*, *Taraxacum nigricans* agg. and *Carex curvula*. *Plantago gentianoides* is a good moisture indicator itself. In comparison to the drier *Omalotheco-Alopecuretum gerardii*, the abundance of drought-tolerant taxa such as *Omalotheca supina*, *Alopecurus gerardii*, *Dianthus microlepis* and *Scleranthus perennis* subsp. *marginatus* decreases.

The stands are composed of two layers, including the low-grown herb layer dominated by *Plantago gentianoides* and subdominated by *Arenaria biflora*, *Nardus stricta*, *Taraxacum nigricans* agg. and *Carex curvula*. Mosses and lichens are represented by dominant *Polytrichum piliferum*; *Lepraria incana*, *Stereocaulon alpinum* and *Cetraria islandica* are also frequent, although their cover values are lower than with the *Omalotheco-Alopecuretum gerardii*.

Plantago gentianoides and *Cerastium cerastoides* are regional character species of the *Soldanello-Plantaginietum gentianoidis* in the Pirin Planina Mts.

As seen from Tab. 7 the Bulgarian *Plantago gentianoides* community can be identified with the *Soldanello-Plantaginietum gentianoidis* Boşcaiu 1971. The floristical differences within the *Soldanello-Plantaginietum gentianoidis* are depicted by geographical races. The community described from the Țarcu, Godeanu and Cernei Mts. (Boşcaiu 1971), Făgăraș Mts. (Csűrös 1957, Pușcaru-Soroceanu et al. 1977) and the Retezat Mts. (Csűrös et al. 1956) is the *Luzula alpino-pilosa* race, characteristic of the Rumanian Carpathians (Tab. 7 hoc loco, columns 1-3). It is differentiated by *Luzula alpino-pilosa*, *Festuca supina*, *Polytrichum norvegicum*, *Carex pyrenaica*, *Rhododendron myrtifolium* (syn. *R. kotschyi*) and *Phyteuma confusum*. The *Soldanello-Plantaginietum gentianoidis* from the Pirin Planina Mts. is assigned to the *Alopecurus gerardii* race (Tab. 7, column 5). It is differentiated by *Alopecurus gerardii*, *Carex curvula*, *Achillea clusiana*, *Scleranthus perennis* subsp. *marginatus* and *Jasione bulgarica*.

The *Nardo-Plantaginietum gentianoidis* (Lakušić et al. 1979) from the Vranica Mts. (Yugoslavia) is identical with the *Soldanello-Plantaginietum*. Based on taxa such as *Crepis aurea* subsp. *glabrescens* (incl. *C. bosniaca* Maly), *Carex curta*, *Festuca picta* and *Sedum alpestre* (incl. *S. horakii*), an eastern - Dinaride race (Tab. 7, column 4) within the *Soldanello - Plantaginietum* can be recognized. The homonymous "Association *Nardus stricta - Plantago gentianoides*" (Ganchev 1963) from the Rila Planina Mts. is a transition-mire community found at peaty margins of glacier lakes.

Omalotheco-Alopecuretum gerardii ass. nova
Nomenclatural type: Tab. 6, relevé 11, hoc loco

The *Omalotheco-Alopecuretum gerardii* is a widely distributed snow-bed community of the Pirin Planina Mts. It was found in broad glacial valleys and circles of the granitic Pirin Planina Mts. (the Solishcheto Saddle, Smirneniski and Belemeto Tsirkus, the Tipits Mts.). The community was sampled also in the Rila Planina Mts. as documented by the following relevé:

Rila Planina Mts., a saddle near the Vazela Mt., 2600 m, aspect ENE, slope 35°, area 16 m², cover of herb layer: 75%, cover of moss layer: < 1%; August 11, 1978.

Alopecurus gerardii 3, *Omalotheca supina* 2-3, *Campanula alpina* subsp. *orbelica* 2, *Dianthus microlepis* 1, *Poa media* 1, *Sedum alpestre* 1, *Taraxacum* sp. 1, *Luzula spicata* +, *Scleranthus perennis* subsp. *marginatus* +, *Arenaria biflora* +, *Polytrichum* sp. +, *Cetraria islandica* +.

References to snow-bed communities with *Alopecurus gerardii* from the Rila Planina Mts. were made by Rusakova (1977) and Rusakova-Anastasova (1983). Grebenshchikov (1965) and Jovanović et al. (1975) mentioned the occurrence of these communities also from other south-Balkan mountains.

Unlike the *Soldanello-Plantaginietum gentianoidis*, this community prefers convex forms of relief. The sites face various aspects; the slopes have a gentle inclination, but are still well-insolated and exposed to winds. Especially in saddles, cryoturbation forms a great variety of habitats suitable for the community. In some places the development of deeper soils is prevented by co-action of wind and snow cover, and large soil-free patches are formed. The bottom of the patches is covered by denuded granite boulders and gravel-like eroded material derived from the granitic rocks. Thick rhizomes of *Alopecurus gerardii* penetrate to the ground surface to form a unique worm-like plexus solidifying the substratum. Among these, abundant *Omalotheca supina*, *Dianthus microlepis*, *Campanula alpina* subsp. *orbelica* and *Scleranthus perennis* subsp. *marginatus* occur. The lower herb sublayer is only few cm high. The culms of *Alopecurus gerardii*, *Luzula spicata* and flowering shoots of *Achillea clusiana* attain the maximal height of 10 to 15 cm, and form the upper herb sublayer. The cryptogamic layer covers usually a quarter of the surface, and is composed of few mosses (the abundant one is *Polytrichum alpinum*) and lichens, which dominate the stands in the driest habitats (the *euphrasietosum minima*).

Most of the stands are grazed by sheep and sustain heavy trampling as becomes obvious along touristic tracks.

The character species of the association is *Alopecurus gerardii*. The group of the association differential species includes drought-tolerant taxa characteristic of acid grasslands of the *Seslerion comosae*, such as *Festuca riloensis*, *Thymus balcanus*, *Campanula alpina* subsp. *orbelica*, *Vaccinium gaultheroides*, *Euphrasia minima*, *Festuca supina* and *Agrostis rupestris*. Also a lichen - *Baeomyces roseus* - should be listed among the differential species.

Three subassociations were distinguished within the *Omalotheco-Alopecuretum gerardii* such as the *plantaginetosum gentianoidis*, the *typicum*, and the *euphrasietosum minimae*. The differentiation of the subassociations is underlied by soil-moisture gradient, and is stressed by the degree of drought tolerance of differential species groups.

The *Omalotheco-Alopecuretum plantaginetosum gentianoidis* subass. nova (nomenclatural type: relevé 6 in Tab. 6 hoc loco) is a transitional unit to the *Soldanello-Plantaginetum gentianoidis*. It occurs in the Belemeto Tsirkus and on the north-facing slope of the Mozgoviskhi Chukar Mt. (2605 m). The stands on gentle slopes and the soils are the richest in fine material within the range of the association. The community houses a number of moisture-loving species which occur only with low abundance values in the other subassociations of the *Omalotheco-Alopecuretum gerardii*. It is the species-poorest snow-bed community. *Plantago gentianoides*, *Alopecurus gerardii*, *Omalotheca supina* and *Taraxacum nigricans* agg. are the dominants of the *Omalotheco-Alopecuretum gerardii plantaginetosum*. The differential species of the subassociation are *Plantago gentianoides* and *Ligusticum mutellina*. *Taraxacum nigricans* agg. has the highest cover values in this subassociation.

The subassociation *typicum* subass. nova (the nomenclatural type is identical with that of the association) is a widely distributed vegetation type occupying an intermediate position within the *Omalotheco-Alopecuretum gerardii* along gradients of soil-moisture and content of fine-soil particles. The group of differential species of the subassociation consist of *Acinos alpinus*, *Luzula spicata* and *Lophozia ventricosa*.

The subassociation *euphrasietosum minimae* subass. nova (nomenclatural type: relevé 18 in Tab. 6 hoc loco) occupies the driest positions along the soil-moisture gradient within the association. It was located in the Demirkapiiska Reka Valley and at the Tipits Mt. The stands of this community are extremely low-grown (2-5 cm); the cryptogamic layer is rich in lichens such as *Lepraria incana*, *Stereocaulon alpinum*, *Cetraria islandica*, *Cladonia macrophyllodes* and *Solorina crocea*. The differential species of the subassociation include *Euphrasia minima*, *Agrostis rupestris*, *Festuca supina*, *Ranunculus pseudomontanus*, *Potentilla aurea* subsp. *chrysocraspeda*, *Nardus stricta*, *Plantago atrata* and *Hypnum cupressiforme* and *Rhacomitrium canescens*. The *Omalotheco-Alopecuretum euphrasietosum* is a snow-bed community of siliceous substrata, with a high abundance of *Plantago atrata* which, however, is more frequent in snow-beds on calcareous bedrocks. Incidental-

Tab. 6 - Snow bed communities on siliceous substrata.

No. of relevé	111111111122	C1	C2
	1234 56789012345678901	%	%
Exposition	W E N N S N S S ----- WNNWWWWSESWWNW-WN		
Slope °	1 11<1215<1 11 12 ----- 5500505005050505-50		
Sampled area m²	1 11 1 1 1 8904 22933342608928649		
Cover of herb layer %	1111 1 9997 00008669795678906 0050 00000000000050000		
Cover of moss layer %	<22 2 2 11 <33321< 2 1001 0550-555500000555		

CARICETEA CURVULAE			
Dianthus microlepis	..3. .2322.352223453.	25	76
Carex curvula	7343 32.2.23..2.53...3	100	53
Poa media	2.35 .4.22...553..42	75	47
Scleranthus * marginatus	.12. ...2..52...323.2	50	41
Primula minima	+++ 3.....	0	6
Jasione * bulgarica	..4. ....2.....3.	25	12
Juncus trifidus	+++3.....	0	6
Poa laxa	+++3.....	0	6
LIGUSTICO-PLANTAGINETUM GENTIANOIDIS			
Plantago gentianoides (Ch)	8887 778.....2.....	100	24
Cerastium cerastoides (Ch)	2..2	50	0
OMALOTHECO-ALOPECURETUM GERARDII			
Alopecurus gerardii (Ch)	.2.3 77778777777887777	50	100
Campanula * orbelica (D)	+++ 2.2223322.223246	0	88
Geum montanum (D)	+++ 2.....1.22...12	0	35
Festuca riloensis (D)	+++ ..2.323.....5	0	29
Thymus * polytrichus (D)	+++ ..322.2.....2.	0	29
Baeomyces roseus (D)	+++ 4.....22.....	0	24
Vaccinium gaultheroides (D)	+++ 2.....2.....	0	18
D-EUPHRASIETOSUM MINIMAE			
Euphrasia minima	+++4334	0	24
Agrostis rupestris	+++3223	0	24
Festuca supina	+++456.	0	18
Rhacomitrium canescens	+++4..2	0	12
Ranunculus pseudomontanus	..3. 22...21.2.2.555.	25	53
Nardus stricta	3743 ...2...2...2.553.	100	29
Potentilla * chrysoptera	3.4. ...2..22...343.	50	35
Plantago atrata	..3. ..2.....442.	25	24
Hypnum cupressiforme	.2.. .....242.	25	18
SALICETEA HERBACEAE			
Omalotheca supina	2323 73375557374778767	100	100
Arenaria biflora	7474 .2223...2323..2.	100	53
Achillea clusiana	2..2 ..5...32322...	50	35
Sedum alpestre	..2 .....1222.3..22	25	41
Ligusticum mutellina	32.. ..2.....	50	12
Luzula spicata	+++232.....	0	18
Soldanella pusilla	..3 .....2.....	25	6
Ranunculus crenatus	..2 .....1.....	25	6
Luzula spadicata	+++2.....	0	6
OTHER PHANEROGAMS			
Taraxacum sp.	7237 553.2...12333...	100	53
Acinos alpinus	+++ ..22.2.....	0	18
Jovibarba heuffelii	+++1.....	0	6

Thymus x pilisiensis	.... .3.....	0	6
OTHER CRYPTOGRAMS			
Polytrichum piliferum	2752 2245.33..67744444	100	82
Cetraria islandica	2... 2..2.222...222222	25	65
Lepraria incana	.34. .2.....3345236	50	47
Stereocaulon alpinum	.22. .2...23...2..22..	50	35
Lophozia ventricosus	...2 .....345....	25	18
Cladonia macrophyllodes	..2. ....22.2.	25	18
Solorina crocea	.... .2...2	0	12
Cladonia pyxidata	.... .2.....	0	6
Cladonia sp.	.... .2.....	25	18
Lecidea sp.	.... .2.....	0	6
Myurella julacea	2... .3...	25	6

Notes: x - hybrid; for other abbreviations see Tab. 1.

ly, this is the only calciphilous species which does occur on silicate snow-beds. On the other hand, the number of the acidophilous elements growing also on calcareous bedrocks is much higher (eg. *Gentiano-Plantaginetum atratae trifolietosum orbelici*; Tab. 7).

Simon (1958) considered *Alopecurus gerardii* to be a character species of the *Seslerietalia comosae*. Horvat (in Horvat et al. 1974) described the *Alopecuro-Plantaginetum* from Pelister Mts. (Yugoslavia Macedonia). According to Horvat et al. (l.c.) this community has an outrageous position within the *Seslerion comosae* as it occurs on fine-grained soil and at less exposed habitats than other communities of the alliance. It differs from the *Omalotheco-Alopecuretum* by presence of the association character species such as *Plantago holosteum*, *Lotus corniculatus* and *Thesium alpinum*, and by absence of many species of the snow-bed habitats. *Alopecurus gerardii* (var. *pantocsekii*) is one of the dominating species of the *Ranunculetum crenati* Lakušić 1966 described from Bjelasica Mts. in Yugoslavia.

Quézel (1964, 1967) regarded *Alopecurus gerardii* as a character species of the *Caricetea curvulae*. Three associations dominated by the species were described by Quézel (l.c.) from the Greece mountains, belonging to the *Trifolion parnassi* Quézel 1964 (the *Trifolietalia parnassi* Quézel 1964, *Caricetea curvulae*). The community group is vicariant to the *Nardion* Luquet 1926 of the temperate Europe. The communities are confined to shallow hollows or small-sized dolinas filled by silt. These habitats contain snow longer than the surrounding environments although they cannot be classified as true snow-beds characteristic of the temperate and boreal mountain ranges. In summer, the soil surface in the sites desiccates. The *Croco sieberi* - *Alopecuretum gerardii* Quézel 1964 (syn. *Beto nanae-Alopecuretum gerardii* (Quézel 1964) Horvat et al. 1974) was described from the Taygetos, Kyllini and Parnassos Mts., the *Gnaphalio hoppeani-Alopecuretum gerardii* Quézel 1967 is known from the Thessalian Olymbos, and the *Croco veluchensis-Alopecuretum gerardii* Quézel 1967 was found to occur in the central and northern parts of the Pindos Mts. (Quézel 1964, 1967, Horvat et al. 1974).

Analogous *Alopecurus gerardii* communities were described from the Djurdijura Mts. in north Africa (Quézel 1957), Maritime Alps in France (eg. Guinochet 1938, Barbero 1970, Lacoste 1975: *Ranunculo pyrenei* - *Alopecuretum gerardii*) and Pyrenées (Lüdi 1943, Braun-Blanquet 1948: *Trifolio* - *Phleetum gerardii*).

Tab. 7 - Communities of the *Salicetea herbaceae* (with *Plantago gentianoides*, *Ranunculus crenatus* and *Alopecurus gerardii*) in the Balkan Peninsula.

Number of column	1	2	3	4	5	6	7	8	9	10	11	12	13
Relevés per table	8	5	6	4	4	7	10	4	9	8	10	9	17
SALICETEA HERBACEAE													
<i>Plantago gentianoides</i>	V24	V+3	V15	434	434	V+		II23	II+	III+			II+4
<i>Ranunculus crenatus</i>	I+	II+1	II+	1+	1+	V23	V24	423	V13	V24	V+3	V14	Ir
<i>Alopecurus gerardii</i>					2+1				III13		II12	V13	V34
<i>Omalothea supina</i>	III+	III+	IIIr+	21	4+1	V+2	V+1	2+3	IV+2	II+	V15	V14	V24
<i>Geum montanum</i>	IV+	II+	III+1	2+1		V+2	III+	11	II+	V+1	V+2	V+2	IIr+
<i>Luzula alpino-pilosa</i>	V+1	I+	III1			III+	V+1	2+	II+1	IV+2			I+
<i>Sedum alpestre</i>				III+	1+	V+1	II+	11	I+	I+	III+2	IV12	IIIr1
<i>Soldanella pusilla</i>	V+2	V13	V+1	11				4+2		V14			I+
<i>Ligusticum mutellina</i>	V+2	III+	V13	412	2+1	V23	IV+2	4+3	II+	IV+1	IV+2		I+
<i>Polytricum norvegicum</i>		I+	III+1				IV+2		I+	II+			
<i>Arenaria biflora</i>			IV+		423			2+2				I2	III+1
<i>Tanacetum alpinum</i>	I+						I+		III12	IV+	I2		
<i>Cerastium cerastoides</i>		I+			2+				III1			IV+2	
<i>Plantago atrata</i>					11	I+					II13	III13	II+2
<i>Achillea clusiana</i>					2+								II+3
<i>Luzula spicata</i>												I+	I+
<i>Salix herbacea</i>							I1		I+				
<i>Kiaeria starkei</i>							III+3				I4		
<i>Soldanella hungarica</i>							V+2						
<i>Kiaeria falcata</i>							III23						
<i>Anthelia juratzkana</i>							III+2						
<i>Polygonum viviparum</i>											I+		
<i>Veronica alpina</i>											I1		
CARICETEA CURVULAE													
<i>Potentilla * chryocraspeda</i>	IV+1	I+	III+2	31	212	V+2		12	II+	IV+	IV+2	V13	II12
<i>Festuca supina</i>		II	III+5			IV+		1+	II+			I+	I2
<i>Primula minima</i>	I+					V+2	IV+1	1+	III+1	IV+1			r1
<i>Agrostis rupestris</i>						V12	I+		III2	I+	II		II+1
<i>Juncus trifidus</i>						II+			II+	I+		II+	I1
<i>Carex curvula</i>					413		II+1	12	I+				
<i>Poa media</i>					3+3							II2	III+3
<i>Ranunculus montanus agg.</i>					11		I+				II+1		IIIr2
<i>Campanula * alpina</i>	II+								I+	II+			
<i>Hieracium alpinum</i>	I+					II+			I+				
<i>Pulsatilla alba</i>	II+					II+				I+			
<i>Phyteuma confusum</i>			II+1						II+		I+1		
<i>Scleranthus * marginatus</i>					2r+							II1	III+3
<i>Festuca riloensis</i>											V+2		II+2
<i>Jasione orbiculata</i>											III+2	V+4	
<i>Anthoxanthum alpinum</i>				11									
<i>Leontodon helveticus</i>				11						I+			
<i>Dianthus microlepis</i>					11						II		III+2
<i>Jasione bulgarica</i>					12								I+1
<i>Poa disparilis</i>			II				III+2						
<i>Campanula tatrae</i>						III+							
<i>Campanula * orbelica</i>													V+2
<i>Avenula versicolor</i>										I+			
<i>Gentiana punctata</i>						I+							
<i>Oreochloa disticha</i>						I+							
<i>Anthemis carpatica</i>								1+					
<i>Festuca * scardica</i>												III2	
<i>Jovibarba heuffelii</i>													Ir
<i>Euphrasia minima</i>													II12
THLASPIETEA ROTUNDIFOLII													
<i>Cardamine rivularis</i>								1+					
<i>Saxifraga muscosa</i>									I+				
<i>Doronicum carpaticum</i>								1+					
<i>Poa laxa</i>													I1
<i>Crepis * glabrescens</i>				31							II13	II14	
<i>Myosotis alpestris</i>											I+		
<i>Festuca picta</i>				412									
<i>Cardaminopsis ovirensis</i>		I+											
<i>Arabis alpina</i>							I+						
<i>Saxifraga androsacea</i>							I+				I1		
OTHER PHANEROGAMS													
<i>Nardus stricta</i>	V+2	I1		434	413		I+		II1	V12	II+2	I+	II+2
<i>Taraxacum sp. div.</i>	II+				4+3	V+		2+1	I+	II+	I1		I+
<i>Poa alpina</i>	I+	IV+2	II+	2+2		III+			III+1	IV+1	II+1		
<i>Homogyne alpina</i>	V+1			21		V+							
<i>Deschampsia caespitosa</i>				11		I+	II+1				I1		
<i>Phleum alpinum</i>		I+		1+		IV+2							

Carex pyrenaica	III3	I+								I+									
Alchemilla glaucescens		I+		2+1															
Veratrum album			I+						I+		I+								
Soldanella alpina				2+															
Avenella flexuosa				1+															
Luzula sudetica				11															
Carex foetida																			
Crocus heuffelianus	II+																		
Saxifraga heucherifolia		I+																	
Trifolium pallescens		I+																	
Carex curta				3+1															
Poa sp.				11															
Gentiana acaulis				1+															
Crocus neapolitanus				11															
Euphrasia stricta								IV+											
Achillea distans								I+											
Alchemilla glabra									I+										
Saxifraga stellaris									I+										
Sesleria bielzii										II+									
Primula veris											I+								
Homogyne discolor																			
Alchemilla plicatula																			
Silene pusilla																			
Luzula campestris																			
Ligusticum albanicum																		III+1	
Thymus * pilosissimus																			I1
Thymus * polytrichus																			II+1

CETRARIO-LOISELEURITEA

Cetraria islandica	II+		I+		1+					I+	IV+1	III2		IV+
Vaccinium gaultheroides												I+		I+
Vaccinium myrtillus	I+			1+										
Rhododendron myrtifolium			II+1			I+								

OTHER CRYPTOGRAMS

Polytrichum piliferum				11	4+3							I+	V+3
Polytrichum juniperinum				11						II+	V+3		
Dicranum scoparium	II+									II+			
Lepraria incana					212								III+2
Stereocaulon alpinum					2+								II+1
Cladonia macrophyllodes					1+								I+
Myurella julacea					1+								II2
Lophozia ventricosa											12		I+2
Hypnum cupressiforme					1+								
Sanionia uncinata						I+				I+			
Polytrichum alpinum	I+												
Oligotrichum hercynium						II23							
Diplophyllum taxifolium						II+1							
Dicranella heteromalla						II+1							
Cladonia pyxidata											I+		
Tortella tortuosa											11		
Rhacomitrium canescens													I+2
Solorina crocea													I+
Cladonia sp.													I+
Baeomyces roseus													II+2

Localities of tables (Tab. 7):

1. Soldanello (pusillae)-Plantaginetum gentianoidis; Resmeriță (1976), Tab. 8; Rodna (Rumania)
2. Soldanello pusillae-Plantaginetum gentianoidis; Resmeriță (1979), Tab. 6. Rodna (Rumania)
3. Ligustico-Plantaginetum gentianoidis; Mucina (ined.); Făgăraș (Rumania)
5. Ligustico-Plantaginetum gentianoidis; Tab. 6 in this study, relevés 1-4; Pirin
6. Agrosteto (alpinae)-Ranunculetum crenati; Resmeriță (1975), Tab. 2; Maramureș (Rumania)
7. Soldanello hungaricae-Ranunculetum crenati; Coldea (1985); Tab. 1; Rodna (Rumania)
8. Soldanello pusillae-Ranunculetum crenati; Mucina (ined.); Făgăraș (Rumania)
9. Soldanello (pusillae) - Ranunculetum crenati; Boșcaiu (1971), Tab. 24, Țarcu, Godeanu & Cernei Mts. (Rumania)
10. Soldanello (pusillae)-Ranunculetum crenati; Resmeriță (1976), Tab. 3; Retezat Ms. (Rumania)
11. Ranunculetum crenati vranicensis; Lakušić et al. (1979), Tab. I (7 rels.); Vranica (Yugoslavia)
12. Ranunculetum crenati; Lakušić (1964-1966), Tab. 2, relevés 1-2, 6-12; Bjelilo (Yugoslavia)
13. Omalothecho-Alopecuretum gerardii; Tab. 6 in this study, relevés 5-21; Pirin

Gentiano-Plantaginetum atratae ass. nova
Nomenclatural type: Tab. 8, relevé 9, hoc loco

The *Gentiano-Plantaginetum atratae* is a typical snow-bed community of the northern range of the Pirin Planina Mts. It is limited to habitats which are covered app. 6 months by snow and occur at altitudes between 2400 and 2600 m. The community is found, unlike the *Bartsio-Salicetum reticulatae*, on convex relief forms, usually with gentle (10 to 15°), east to south - (southeast) - facing slopes. The habitats are more insolated but also windier than those of the *Bartsio-Salicetum reticulatae*.

The soils, shallow alpine rendzinas, are derived from two types of rocks such as calcium-rich schists and crystalline limestones (marble). The substratum is very skeletal; the skeleton covers a small part of the soil surface. On schists, the upper soil layer is rich in gravel-like skeleton.

The stands of the community are low-grown and two-layered. The herb layer, usually with high cover (70 to 90%) is composed of two sublayer which are not always developed. The low sublayer (3 to 5 cm) is dominated by *Plantago atrata* which gives the stands an outlook of a silvery carpet. Only occasionally some grasses and sedges, such as *Alopecurus gerardii*, *Poa pirinica*, *Sesleria coerulans* and *Carex kitaibeliana* overtop the sublayer and form the higher herb sublayer usually attaining 10 to 15 cm in height. The dense carpet of *Plantago atrata* is penetrated by dwarf herbs such as *Gentiana verna*, *Ranunculus carinthiacus* (see Kožuharov & Petrova 1988), *Omalotheca supina*, *Arenaria biflora*, *Sedum atratum*, *Potentilla crantzii*, *P. aurea* subsp. *chrysocraspeda*, *Dianthus microlepis*, *Campanula alpina* subsp. *orbelica*, *Euphrasia minima*, *Galium stojanovii*, *Oxytropis urumovii* and *Draba scardica*.

The community is found in patches amidst of calcareous alpine grasslands. The appearance of stands of this community indicates a good potential to sustain trampling as we also observed in areas heavily affected by mountain walkers and alpinists, for instance in the Premkata Saddle (2650 m). The stands of the *Gentiano-Plantaginetum* have not changed markedly in this location during the observed period of 1978-1984, although the number of tourists kept increasing year to year. The dense low-grown carpet serves a good anti-erosion function.

The character taxa of the *Gentiano-Plantaginetum* are *Plantago atrata*, *Gentiana verna*, *Potentilla crantzii* and *Ranunculus carinthiacus*. The group of differential species of the *Gentiano-Plantaginetum* is composed of a number of indicators of siliceous substrata, such as *Alopecurus gerardii*, *Dianthus microlepis*, *Campanula alpina* subsp. *orbelica*, *Acinos alpinus*, *Euphrasia minima*, *Trifolium repens* subsp. *orbelicum* and the like (Tab. 8). *Asplenium fissum* and *Alyssum cuneifolium* subsp. *pirinicum*, which are characteristic of skeletal soils or rocky habitats, can be also considered differential for the *Gentiano-Plantaginetum*. Of cryptogams *Leskea polycarpa*, *Psora decipiens* and *P. lurida* are also differential for the *Gentiano-Plantaginetum*.

Two subassociations were distinguished within the association, the *typicum*

Tab. 8 - Communities of the Salicion retusae.

No. of relevé	1111111	C1	C2
	123456789 0123456	%	%
Exposition	SS E		
	N SS N N N		
	ESEEEEESEW EN-ENW-		
Slope °	1111221 1 23 223<		
	500005050 00-0005		
Sampled area m²	1111111 111		
	042652289 4750226		
Cover of herb layer %	1		
	999789799 0899887		
	055050005 0000505		
Cover of moss layer %	1<21< <1 <1< 1 6		
	05051-150 1055050		

GENTIANO-PLANTAGINETUM ATRATAE

Plantago atrata (Ch)	888778888 .2.32..	100	43
Gentiana verna (Ch)	244433323 .3.22..	100	43
Acinos alpinus (D)	22.5.4.2.	56	0
Leskea polycarpa (D)	..3..22.	33	0

D-TRIFOLIETOSUM ORBELICI

Campanula * orbelica	222.23... ..	56	0
Draba scardica	.12222... ..	56	0
Trifolium * orbicolum	.362.5... ..	44	0
Alopecurus gerardii	..6346... ..	44	0
Euphrasia minima	.352... ..	33	0
Botrychium lunaria	.2.4... ..	22	0
Dianthus microlepis	222.3... ..	44	14
Artemisia eriantha	.3.6.2... ..	33	29
Potentilla * chrysaspeda	..55... ..	22	29

BARTSIO-SALICETUM RETICULATAE

Salix reticulata (Ch)	..... 9899848	0	100
Bartsia alpina (Ch)	..... .22.43.	0	57
Polygonum viviparum (Ch)	..... 33.52.2	0	71
Erigeron vichrenensis (Ch)	..2..... .122..2	11	57
Dryas octopetala (Ch)	..... .7.	0	14
Ditrichum flexicaule (D)	..... .532335	0	86
Mnium stellare (D)	..... .3..322	0	57
Pinguicula balcanica (D)	..... .2..52.	0	43
Saxifraga androsacea (D)	..... .3...2	0	29
Saxifraga ferdinandi-coburgi (D)	..... 2...2.	0	29
Silene * graefferi (D)	..... 2..2...	0	29
Saxifraga oppositifolia (D)	...2...2. .42.335	22	71
Primula minima (D)	..2..... .5.5	11	29

ARABYDETALIA CAERULEAE

Carex kitaibeliana	.525.2.32 .32557.	67	71
Carex * pirinica	..22...56 .3323.2	44	71
Poa pirinica	..5.2342. 3.3...2	56	43
Potentilla crantzii	364444.37 3.23...	89	43
Ranunculus carinthiacus	.2332..53 3..3...	67	29
Sedum atratum	22122... ..	56	29
Primula halleri	...2...22 311...	33	57
Viola grisebachiana	...2... .. 23... ..	11	29

SALICETALIA HERBACEAE & SALICETEA HERBACEAE

Omalothea supina	.22422253 222... ..	89	43
Arenaria biflora	2322.2355 2222..2	89	71
Phleum * rhaeticum	.....22 ..2...	22	14
Veronica alpina	.....2 ..2...2	11	29
Achillea clusiana	.....3... ..	11	0
Geum montanum	..2... ..	11	0
Sedum alpestre	.....2... ..	11	0
Luzula spadiacea	....2... ..	11	0

ARABIDETALIA ALPINAE-FLAVESCENTIS

Armeria * alpina	.2252.352	24..323	78	71
Galium stojanovii	24252325.	2322...	89	57
Myosotis alpestris	..22.2322	32.2..2	67	57
Veronica * kellereri	.2.33.3..	232...2	44	57
Thlaspi * bellidifolium	22.2..2..	.2.....	44	14
Saxifraga * discolor	...2.1..	.....2	22	14
Alyssum * pirinicum	.....22.	.....	22	0
Arenaria pirinica	...23...	.....	22	0
Saxifraga luteoviridis	...2.....	.....3.	11	14
Arabis caucasica	.....2..	.....	11	0
Myosotis suaveolens	.....2	.....	0	14

THLASPIETEA ROTUNDIFOLII

Doronicum columnae	.....3..	.2..1.2	11	43
Polystichum lonchitis	.....2..	.....	11	0
Sagina saginoides	.....2	.2....	11	14
Geum reptans	.....	..5....	0	14

FESTUCO-SESLERIETEA

Cerastium * lanatum	753233.22	3.22..3	89	57
Sesleria coerulans	.2323.42.	433443.	67	86
Pedicularis verticillata	...2...2.	22.332.	22	71
Poa alpina	.3.2...63	.235..	44	43
Oxytropis urumovii	.5..3...+	2..2...+	22	29
Androsace * arachnoidea	.....2...+	2.....	11	14
Anthyllis * vitellina	3.....	..2....	11	14
Aster * dolomiticus	2.....	...1...	11	14
Onobrychis * scardica	.....3...+	2.....	11	14
Trifolium badium	..3.....	.....	11	0
Carex rupestris	...6.....	33.....	11	29

CARICETEA CURVULAE

Saxifraga * exarata	...2.....	.....3	11	14
Scleranthus * marginatus	2.....	.....	11	0
Festuca riloensis	2.....	.....	11	0
Hieracium alpicola	2.....	.....	11	0
Leontodon * riloensis	..4.....	.....	11	0
Poa ursina	2.....	.....	11	0
Sesleria comosa	2.....	.....	11	0
Knautia midzorensis	...2.....	.....	11	0
Juniperus * nana	.....	..1....	0	14

ASPLENIETEA TRICHOMANIS

Silene pusilla	...2.....	.2....3	11	29
Asplenium fissum	...2..2..	.....	22	0
Euphrasia salisburgensis	...2.....	.....	11	0
Minuartia verna	2.....	.....	11	0
Potentilla * stojanovii	.....	...1..	0	14
Thymus cherlerioides	.2.....	.....	11	0

OTHER PHANEROGAMS

Taraxacum nigricans agg.	.2.23.432	232.2..	67	57
Gentianella sp.	.....	...2...	0	14

OTHER CRYPTOGAMS

Tortella tortuosa	..32..2.2	22.2.5.	44	57
Hymenostylium recurvirostre	...5....5	.52.53.	22	57
Cladonia sp.	332.....	...2...	33	14
Polytrichum juniperinum	.35.3....	...5...	33	14
Bryum caespitium	...2.....	.2....	11	14
Psora decipiens	.2.....2	.....	22	0
Psora lurida	...3...2.	.....	22	0
Catopryrenium cinereum	.2.....	.....	11	0
Cladonia symphyocarpa	.....3	.....	11	0
Tortulla sinensis	.2.....	.....	11	0
Trichostomum crispulum	.....2..	.....	11	0
Bryum elegans	.....	2...2..	0	29
Cetraria islandica	.....	...23	0	29
Cladonia pocillum	.....	...37	0	29
Peltigera rufescens	.....	..2...3	0	29
Preissia quadrata	.....	.2....2	0	29

Solorina bispora	.....2...3.	0	29
Blepharostoma trichophyllum	.....2.	0	14
Collema sp.	.....2..	0	14
Crataneuron filicinum	.....3....	0	14
Distichum capillaceum	.....2....	0	14
Hypnum cupressiforme	.....3....	0	14
Lepraria incana	.....2..	0	14
Lophocolea minor	.....2.	0	14
Stereocaulon alpinum	.....2.	0	14

Notes: C1 - constancy of Gentiano-Plantaginietum; C2 - constancy of Bartsio-Salicetum; for other abbreviations see Tab. 1.

subass. nova (the nomenclatural type is identical with that of the association) and the *trifolietosum orbelici* subass. nova (nomenclatural type: relevé 3 in Tab. 8 hoc loco). The differentiation of the subassociations is based both on character of bedrock and presence of species groups. The typical subassociation occurs on marble, where as the *trifolietosum orbelici* is found on calcium-rich schists characteristic by plate separation of comparative more fragile bedrock. This type of bedrock is found usually along tectonic faults at contact zones between granites and crystalline limestones. The community was localized in the Kabata and Premkata Saddles, south and north of the Vikhren Mt., respectively, and near to the Kamenishki Vrah Mt. (2533 m). The stands were found on gentle, prevailingly east-facing slopes. The south aspect is common with the typical subassociation. The *trifolietosum orbelici* is a typical ecotone community housing the highest number of vascular species of all snow-bed communities in the area regardless the bedrock. The community is a transitional unit between the *Gentiano-Plantaginietum atratae* and *Omalotheco-Alopecuretum gerardii*. The differential taxa of the *trifolietosum orbelici* (*Trifolium repens* subsp. *orbelicum*, *Alopecurus gerardii*, *Sedum atratum*, *Dianthus microlepis*, *Campanula alpina* subsp. *orbelica*, *Potentilla aurea* subsp. *chrysocraspeda*, *Euphrasia minima*) are typical of the silicate substrata (see Simon 1958). Further also *Acinos alpinus*, *Thymus cherlerioides*, *Artemisia eriantha*, *Draba scardica*, *Botrychium lunaria* and *Arenaria pirinica*, which are limited to calcareous substrata, are considered differential of this subassociation. *Achillea clusiana*, *Scleranthus perennis* subsp. *marginatus*, *Sedum alpestre*, *Primula minima*, *Geum montanum*, *Festuca riloensis*, *Luzula alpino-pilosa*, *Poa media*, *Hieracium alpicola*, *Sesleria comosa* and *Leontodon croceus* subsp. *riloensis* are found only in this type of snow-bed communities on calcareous bedrock, but their ecological optimum lies either in snow-bed habitats on silicate bedrock or on acid alpine grasslands of the *Seslerietalia comosae*.

Plantago atrata includes several subspecies and varieties limited to particular mountain ranges in the Central and south Europe and form a vicariant group of taxa (Hayek 1931, Casper 1974). Feoli-Chiapella & Feoli (1977) reported on a *Plantago atrata* var. *tenuis* dominated community from the Majella Mts. in the Central Apennines. According to the character of habitats and floristic composition (several vicariant taxa occurring in respective communities) the *Gnaphalio-Plantaginietum atratae* Feoli-Chiapella et Feoli 1977 is a vicariant to the *Gentiano-Plantaginietum atratae*.

The *Trifolio-Plantaginietum angustifoliae*, described by Lakušić (1966) from Bjelasica Mts. in Yugoslavia is floristically probably the most similar community to

the *Gentiano-Plantaginietum atratae*. From the *Gentiano-Plantaginietum* the former one differs by dominance of *Crepis aurea* subsp. *glabrescens* (syn. *C. columnae*), *Soldanella alpina*, *Taraxacum* spp. and *Trifolium pallescens* and other species of limited distribution (see Tab. 7).

Other *Plantago atrata* dominated communities from the Balkan Peninsula were described from silicate snow-beds. The *Plantaginietum atratae* studied in the Durmitor, Čvrsnica and Prenj Mts. in Yugoslavia by Horvat et al. (1974) differs from the *Gentiano-Plantaginietum atratae* by presence of taxa such as *Crepis aurea* subsp. *glabrescens*, *Arenaria rotundifolia*, *Armeria canescens* and *Viola calcarata* subsp. *zoysii* and several other, mostly acidophilous, taxa. The *Soldanello-Plantaginietum durmitorei*, mentioned from the Durmitor Mts. without a relevé table (Lakušić 1984), is probably identical with the *Plantaginietum atratae*. The *Thlaspi microphylli-Plantaginietum atratae* (see Horvat et al. 1974) known from the Yugoslavian Macedonia is characterized by *Androsace hedraeantha* and *Ranunculus crenatus*. Together with the *Plantaginietum atratae* are, unlike the *Gentiano-Plantaginietum atratae*, classified within the *Salicion herbaceae*.

Bartsio-Salicetum reticulatae ass. nova

Nomenclatural type: Tab. 8, relevé 11, hoc loco

The *Bartsio-Salicetum reticulatae* is another type of a snow-bed community on calcareous substrata. The habitats of the association are exposed to longer-lasting snow period than in the case of the *Gentiano-Plantaginietum atratae*. The community inhabits concave forms of relief sheltered from direct solar irradiation. The stands are found in shallow depressions among large boulders on bottoms of glacial circles or on small-sized terraces with a gentle north-facing slopes.

The soils are alpine rendzinas which contain more silt than those supporting *Gentiano-Plantaginietum atratae*. As a result of higher contents of finer soil particles and long-lasting snow cover the soils are wetter and keep moisture even during hot summers. The desiccation is prevented also by high plant cover which attains 80 to 100% as a rule. The soils are derived from crystalline limestones in all of the studied stands.

The *Bartsio-Salicetum reticulatae* is formed by low-grown stands composed of the herb and moss layers. The lower herb layer is dominated by *Salix reticulata*. Only in one relevé the dominating species was *Dryas octopetala*. The dominants are accompanied by dwarf alpine plants such as *Bartsia alpina*, *Erigeron vichrenensis* Pawlowski, *Polygonum viviparum*, *Primula minima*, *P. halleri*, *Veronica saturejoides* subsp. *kellereri*, *Pedicularis verticillata* and other. The stands of the community are recognizable as dark-green patches. The upper herb sublayer is species-poor (*Carex kitaibeliana*, *C. parviflora* subsp. *pirinica*, *Sesleria coerulans*, *Poa pirinica*, *Armeria pocutica* subsp. *alpina*), and does not overshoot the height of 15 cm. The moss layer is richer in species than with the *Gentiano-Plantaginietum atratae* stands, which also points upon the higher soil moisture. *Saxifraga oppositifolia*, *S. androsacea*, *Pedicularis verticillata* and *Primula minima* also prefer moister

habitats. The stands of the *Bartsio-Salicetum reticulatae* do not suffer from sheep-grazing (perhaps only from slight grazing of mountain goats) as they occur in remote sites in bouldery glacial circles and on exposed terraces.

The character species of the *Bartsio-Salicetum reticulatae* are *Salix reticulata*, *Bartsia alpina*, *Dryas octopetala*, *Polygonum viviparum*, *Gentianella aspera* and *Erigeron vichrenensis*. The latter taxon, endemic to the Pirin Planina Mts. (Pawlowski 1969), has its sociological optimum in the *Bartsio-Salicetum reticulatae* and to a lesser extent it also occurs in the *Papaveri-Armerietum*. The other character species of the *Bartsio-Salicetum* are typical regional character species which occur also in other European high-mountain systems where they show varying sociological valency. *Saxifraga oppositifolia*, *S. androsacea*, *S. ferdinandi-coburgi*, *Pinguicula balcanica*, *Silene ciliata*, *Primula minima*, *Diurichum flexicaule*, *Mnium stellare*, *Bryum elegans*, *Cladonia pocillum*, *Peltigera rufescens*, *Preissia quadrata* and *Solorina bispora* differentiate the *Bartsio-Salicetum reticulatae* from the *Gentiano-Plantaginietum atratae*.

The *Bartsio-Salicetum reticulatae* belongs to a group of vicariant plant associations where in also the *Salicetum reticulatae* from the West Carpathians, *Salicetum retuso-reticulatae* from the Alps, *Dryado-Salicetum reticulatae* and *Salicetum retuso-kitaibelianae* from Yugoslavia (Braun-Blanquet & Jenny 1926, Szafer et al. 1927, Horvat 1936, Beldie 1967, Lakušić 1970) are classified. The *Saxifraga sempervivi-Salicetum reticulatae* (Horvat 1936) appears as floristically close to the *Bartsio-Salicetum reticulatae*, although the occurrence of *Saxifraga sempervivum*, *Omalotheca hoppeana*, *Androsace hedraeantha* and *Saxifraga glabella* in the *Saxifraga-Salicetum* emphasize an important floristic difference between the discussed units. Whereas the *Salicetum retuso-reticulatae*, *Salicetum reticulatae* and *Dryado-Salicetum reticulatae* belong to the *Arabidion caeruleae* Br.-Bl. 1926, the *Saxifraga-Salicetum reticulatae*, *Salicetum retuso-kitaibelianae* and *Bartsio-Salicetum reticulatae* are classified within the *Salicion retusae* Horvat 1949.

Syntaxonomy of the Salicetea herbaceae communities

All known snow-bed communities in Europe are classified within the *Salicetea herbaceae* (Braun-Blanquet 1976, Dierssen 1984). The bedrock differentiation is reflected on the level of orders. The *Salicetalia herbaceae* and *Arabidetalia caeruleae* comprise communities on silicate and calcareous bedrocks, respectively. A number of vicariant alliances were described within each order (see Dierssen 1984 for a review).

The snow-bed plant communities of the Balkan mountain ranges (including the Southern and Eastern Carpathians) used to be separated into the *Ranunculion crenati* (Lakušić 1966, 1970), supposedly a geographic analogon to the *Salicion herbaceae* of the Alps and Carpathians (Lüdi 1921, Braun-Blanquet & Jenny 1926, Krajina 1922, Rübel 1933, Oberdorfer 1977). *Ranunculus crenatus*, *Soldanella pusilla*, *Plantago gentianoides* were listed by Lakušić (1966) as character species of the *Ranunculion crenati*. *Ranunculus crenatus* is distributed mainly in the Balkan

Peninsula, but also occurs in Styria (Steiermark, Austria) in the Rottenmanner Tauern Mts. and Schladminger Tauern Mts. (Müller & Baltisberger 1984). *Plantago gentianoides* is a Balkan endemic, but it occurs also in the *Caricion fuscae* Koch 1926 em. Klika 1934 (Juhász-Nagy 1963, Mucina ined.); *Soldanella pusilla* is common to many Balkan mountains, but occurs also in the Alps in the *Salicion herbaceae* (Braun-Blanquet & Jenny 1926, Braun-Blanquet 1954, Oberdorfer 1977).

Salix herbacea, *Polytrichum norvegicum*, *Kiaeria starkei*, *K. falcata*, *Sibbaldia procumbens*, *Anthelia juratzkana* and many others (Dierssen 1984), considered the character species of the *Salicetea herbaceae* and *Salicion herbaceae*, occur in many snow-bed communities in the Balkans (Horvat et al. 1937, Simon 1958, Lakušić 1966, 1970, Resmeriță 1975, 1978, Coldea 1985, Coldea et al. 1981 etc.). Horvat et al. (1937), Beldie (1967), Pușcanu-Soroceanu et al. (1956), Popescu et al. (1983), Resmeriță (1975, 1978, 1979) and many other report also the *Salicetum herbaceae* Br. - Bl. 1913, *Luzuletum spadiceae* Br. - Bl. 1926 and *Polytrichetum sexangularis* from the Rumanian Carpathians and Bulgaria. However, we do not identify the *Salix herbacea*, *Luzula alpinopilosa* and *Polytrichum norvegicum* dominated communities of the Alps (belonging to the *Salicion herbaceae*) with those of the Balkans. The latter should be considered vicariant units, like in the case of the West-Carpathian snow-patch communities (Dúbravcová in Mucina & Maglocký 1985).

We do not consider the separation of the *Salicion herbaceae* and *Ranunculion crenati* for readily documented, because besides a group of snow-bed communities with their distribution areas exclusively located in the Balkan Peninsula (see the references above and Tab. 7), there are some others (eg. the *Poo-Cerastietum cerastoidis* (Söyrinki 1954) Oberd. 1957 and *Nardo - Gnaphalietum supini* Bartsch 1940) which occur both in the Alps as well as Southern and Eastern Carpathians (already in the Balkans).

It is a general phenomenon that the syntaxa characteristic of calcareous bedrocks in the Balkans can be classified into more vicariant units than those from silicate rocks. This probably goes on the account of high endemism on calcium-rich substrata, relict character of the habitats, higher species-richness, the extent of calcareous substrata especially in the Dinarides, and long-lasting isolation of the mountain summits.

Also the floristic differentiation of the high-ranked syntaxa of communities on the calcareous bedrock is more pronounced. This holds also for the differentiation of the *Arabidion caeruleae* (the Alps, West Carpathians) from the *Salicion retusae* (the Balkan mountains).

Both *Gentiano-Plantaginetum atratae* and *Bartsio-Salicetum reticulatae* are classified within the *Salicion retusae*, an alliance originally described from the Dinarides by Horvat (1949). Balkan endemics such as *Saxifraga sedoides* subsp. *prenja*, *S. sempervivum*, *S. glabella*, *Plantago atrata* var. *angustifolia* Hal. et Bald. and *Androsace hedreantha* are very typical of the alliance.

The *Salicion retusae* belongs to the *Arabidetalia coeruleae*. The status of the *Salicetalia retusae*, a unit suggested by Lakušić (1970), still remains to be cleared.

The syntaxonomic relations of the syntaxa of snow-bed communities in the Balkan Peninsula can be summarized as follows:

Salicetea herbaceae Br.-Bl. 1947

Salicetalia herbaceae Br.-Bl. 1926

Salicion herbaceae Br.-Bl. 1926

(syn. *Ranunculion creanti* Lakušić 1966)

1. *Ranunculo crenati* - *Salicetum herbaceae* (Horvat 1936) Mucina et al. nom. novum hoc loco
(basionym: *Salicetum herbaceae balcanicum* Horvat 1936; syn. *Salicetum herbaceae* sensu auct. balcan.)
2. *Ranunculo crenati* - *Polytrichetum sexangularis* (Horvat 1936) Mucina et al. nom. novum hoc loco
(basionym: *Polytrichetum sexangularis balcanicum* Horvat 1936)
3. *Soldanello pusillae*-*Plantaginetum gentianoidis* Boşcaiu 1971
(syn. *Nardo-Plantaginetum gentianoidis* Lakušić et al. 1979; non *Nardo* - *Plantaginetum gentianoidis* Ganchev 1963)
4. *Soldanello pusillae*-*Ranunculetum crenati* Borza ex Boşcaiu 1971
(syn. *Agrostio rupestris*-*Ranunculetum crenati* Resmeriță 1975 corr. 1978, *Agrostio alpinae*-*Ranunculetum crenati* Resmeriță 1975)
5. *Soldanello hungaricae*-*Ranunculetum crenati* Coldea 1985
6. *Ranunculetum crenati* Lakušić 1966
7. *Soldanello pusillae* - *Luzuletum spadiceae* (Borza 1934) Mucina et al. nom. novum hoc loco
(basionym: *Luzuletum spadiceae retezaticum* Borza 1934)
8. *Soldanello hungaricae*-*Salicetum kitaibelianae* Coldea 1985
9. *Ligustico*-*Caricetum foetidae* Horvat 1960 prov.
10. *Thlaspio microphylli*-*Plantaginetum atratae* Horvat 1936
11. *Plantaginetum atratae* Horvat in Horvat et al. 1974
(syn.? *Soldanello-Plantaginetum durmitorei* Lakušić 1984 nom. nudum)
12. *Omalotheco*-*Alopecuretum gerardii* Mucina et al. 1990
13. *Trifolio* - *Phleetum pantocsekii* Lakušić 1984 nom. nudum?
14. *Nardo* - *Gnaphalietum supini* Bartsch 1940
15. *Agrostio rupestris*-*Gnaphalietum supini* Resmeriță corr. 1978
(syn. *Agrostio alpinae*-*Gnaphalietum supini* Resmeriță 1975)
16. *Poo*-*Cerastietum* (Söyrinki 1954) Oberdorfer 1957

Arabidetalia caeruleae Rübel 1933

(syn. *Salicetalia retusae* Lakušić 1968)

Salicion retusae Horvat 1949

17. *Saxifragetum prenjae* Horvat 1931 (here?)
18. *Saxifrago*-*Rumicetum nivalis* Horvat 1936
19. *Geo*-*Oxyrietum digynae* Horvat 1936
20. *Bartsio*-*Salicetum reticulatae* Mucina et al. 1990

21. *Saxifraga sempervivi-Salicetum reticulatae* (Horvat 1936) Mucina et al.
nom. novum hoc loco
(basionym: *Salicetum retuso-reticulatae macedonicum* Horvat 1936)
22. *Dryado-Salicetum reticulatae* Beldie 1967
(syn. *Salicetum reticulatae* sensu Puşcaru-Soroceanu 1956)
23. *Soldanello-Salicetum retusae* Horvat 1933
(syn. *Soldanello - Salicetum retusae bosniacum* Lakušić et al. 1979)
24. *Anemono-Salicetum retusae* Horvat 1953
25. *Salicetum retuso-kitaibelianae* Lakušić 1970
26. *Gentiano-Plantaginetum atratae* Mucina et al. 1990
27. *Trifolio-Plantaginetum angustifoliae* Lakušić 1966

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Appendix

Localities of the relevés:

Tab. 1. *Hieracio-Caricetum kitaibelianae* (1-9) and *Leontopodio-Potentilletum stojanovii* (10-16).

1. Banderitsa Cottage, Djamdjievite Skali, 2000 m; 8-8-1983 (LM2694).
2. Banderitsa Cottage, Djamdjievite Skali, 2050 m; 8-8-1983 (LM2695).
3. Banderitsa Cottage, Djamdjievite Skali, 2050 m; 8-8-1983 (LM2696).
4. Banderitsa Cottage, Djamdjievite Skali, 2100 m; 8-8-1983 (LM2697).
5. Banderitsa Cottage, Djamdjievite Skali, 1900 m; 8-8-1984 (LM3107).
6. Ridge between Banderitsa Cottage and Malkiya Kazan, 2100 m; 9-8-1983 (LM2699).
7. Banderitsa Cottage, Djamdjievite Skali, 1900 m; 8-8-1984 (LM3106).
8. Banderitsa Cottage, direction Vikhren, 1980 m; 8-8-1984 (LM3110).
9. Malkiya Kazan, direction Banderitsa Cottage, 2000 m; 9-8-1984 (LM3113).
10. Golemiya Kazan, Zaslon Eltepe, 2450 m; 9-8-1984 (LM3117).
11. Golemiya Kazan, flanks of Kutelo Mts., above Zaslon Eltepe, 2500 m; 10-8-1984 (LM3133).
12. Saddle Kabata, 2500 m; 9-8-1983 (LM2707).
13. Banderitsa Cottage, Djamdjievite Skali, 2300 m; 8-8-1983 (LM2698).
14. Malkiya Kazan, 2300 m; 9-8-1983 (LM2702).
15. Ridge between Malkiya and Golemiya Kazan, 2380 m; 10-8-1984 (LM3123).
16. Malkiya Kazan, 2300 m; 9-8-1983 (LM2700).

Tab. 3. *Silene pusilla-Saxifraga oppositifolia* community.

1. Ridge between Banki Sukhodol Mt and Bayuvi Dupki Mt., 2600 m; 13-8-1984 (LM3157).
2. Ridge between Bayuvi Dupki Mt. and Kamenititsa Mt., 2600 m; 13-8-1984 (LM3158).

Tab. 4. *Papaveri-Armerietum alpinae* (1-23) and *Veronico-Silenetum prostratae* (24-29).

1. Golemiya Kazan, 2450 m; 10-8-1984 (LM3127).
2. Golemiya Kazan, 2420 m; 10-8-1984 (LM3132).
3. Tsirkus Kamenititsa, flanks of Bayuvi Dupki Mt., 2750 m; 12-8-1984 (LM3150).
4. Tsirkus Kamenititsa, saddle between Bayuvi Dupki Mt. and Kamenititsa Mts., 2650 m; 12-8-1984 (LM3156);
5. Golemiya Kazan, 2500 m; 10-8-1984 (LM3130).
6. Tsirkus Bayuvi Dupki, 2680 m; 11-8-1984 (LM3145).
7. Golemiya Kazan, 2400 m; 10-8-1984 (LM3125).
8. Tsirkus Kamenititsa, 2500 m; 12-8-1984 (LM3152).
9. Tsirkus Bayuvi Dupki, 2680 m; 11-8-1984 (LM3146).
10. Tsirkus Bayuvi Dupki, 2650 m; 11-8-1984 (LM3147).
11. Malkiya Kazan, 2200 m; 9-8-1984 (LM3115).
12. Golemiya Kazan, 2500 m; 10-8-1984 (LM3128).
13. Golemiya Kazan, S of Zaslon Eltepe, 2500 m; 10-8-1984 (LM3129).
14. Golemiya Kazan, bottom, 2500 m; 10-8-1984 (LM3120).
15. Golemiya Kazan, 2350 m; 10-8-1984 (LM3141).
16. Malkiya Kazan, 2200 m; 9-8-1984 (LM3114).
17. Tsirkus Kamenititsa, 2500 m; 12-8-1984 (LM3153).
18. Golemiya Kazan, 2400 m; 10-8-1984 (LM3124).
19. Kutelo Mt., 2700 m; 11-8-1984 (LM3143).
20. Koncheto Ridge, 2700 m; 11-8-1984 (LM3144).
21. Tsirkus Bayuvi Dupki, 2620 m; 11-8-1984 (LM3148).
22. Golemiya Kazan, 2400 m; 10-8-1984 (LM3140).
23. Tsirkus Kamenititsa, saddle between Bayuvi Dupki Mt. and Kamenititsa Mt., 2650 m; 13-8-1984 (LM3159).
24. Golemiya Kazan, 2400 m; 10-8-1984 (LM3139).
25. Golemiya Kazan, 2400 m; 10-8-1984 (LM3138).
26. Golemiya Kazan, 2400 m; 10-8-1984 (LM3137).

27. Golemiya Kazan, 2450 m; 10-8-1984 (LM3134).
28. Golemiya Kazan, 2450 m; 10-8-1984 (LM3135).
29. Golemiya Kazan, 2400 m; 10-8-1984 (LM3136).

Tab. 5. *Bromo-Geraniumetum macrorrhizi*.

1. Banderitsa Cottage, gorge near Baikushevata mura (old specimen of *Pinus leucodermis*), 1850 m; 8-8-1984 (LM3105).
2. Banderitsa Cottage, 1900 m; 9-8-1984 (LM3111).
3. Banderitsa Cottage, direction Malkiya Kazan, 1950 m; 9-8-1984 (LM3112).
4. Banderitsa Cottage, 1950 m; 8-8-1984 (LM3109).
5. Banderitsa Cottage, 1930 m; 8-8-1984 (LM3108).

Tab. 6. *Ligustico-Plantaginetum gentianoidis* (1-4) and *Omalotheco-Alopecuretum gerardii* (5-21).

1. Smirnenski Tsirkus, Mitrovo Ezero; 6-8-1983 (LM2681).
2. Smirnenski Tsirkus, Mitrovo Ezero; 6-8-1983 (LM2683).
3. Smirnenski Tsirkus, Mitrovo Ezero; 6-8-1983 (LM2684).
4. Tsirkus Belemeto, 2450 m; 7-8-1983 (LM2687).
5. Saddle between Kralev Dvor Mt. and Kamenitsa Mt., 2550 m; 2-8-1978 (LM1619).
7. Saddle between Kralev Dvor Mt. and Kamenitsa Mt., 2550 m; 2-8-1978 (LM1621).
8. South flank of Mozgovishki Chukar Mt., 2520 m; 7-8-1983 (LM2690).
9. Saddle Solishcheto (between Arabski Grab Mt. and Kuklite Mt.), 2410 m; 31-7-1978 (LM1599).
10. Saddle Solishcheto, 2410; 31-7-1978 (LM1608).
11. Saddle Solishcheto, 2350; 31-7-1978 (LM1610).
12. Tevnoto Ezero, Zaslon, 2510 m; 1-8-1978 (LM1615).
13. Saddle between Kralev Dvor Mt. and Kamenitsa Mt., 2600 m; 2-8-1978 (LM1618).
14. Saddle between Kralev Dvor Mt. and Kamenitsa Mt., 2550 m; 2-8-1978 (LM1620).
15. Smirnenski Tsirkus, below Kravevodvorska Porta; 7-8-1983 (LM2685).
16. Tsirkus Belemeto, 2500 m; 7-8-1983 (LM2686).
17. Tsirkus Belemeto, 2500 m; 7-8-1983 (LM2688).
18. Treta Reka Valley; 6-8-1983 (LM2678).
19. Treta Reka Valley; 6-8-1983 (LM2679).
20. Smirnenski Tsirkus, Mitrovo Ezero; 6-8-1983 (LM2680).
21. Ridge between Malk Tipits Mt. and Tipits Mt., 2600 m; 7-8-1983 (LM2691).

Tab. 8. *Gentiano-Plantaginetum atratae* (1-9) and *Bartsio-Salicetum reticulatae* (10-16).

1. Kamenishki Vrah Mt. (2533 m), 2400 m; 7-8-1978 (LM1654).
2. Premkata Saddle, 2600 m; 11-8-1984 (LM3142).
3. Tsirkus Kamenititsa, 2550 m; 12-8-1984 (LM3154).
4. Tsirkus Kamenititsa, 2550 m; 12-8-1984 (LM3155).
5. Premkata Saddle, 2610 m; 9-8-1983 (LM2706).
6. Kabata Tsirkus, 2450 m; 9-8-1983 (LM2708).
7. Golemiya Kazan, 2400 m; 9-8-1983 (LM2701).
8. Golemiya Kazan, Zaslon Eltepe, 2400 m; 9-8-1984 (LM3118).
9. Golemiya Kazan, Zaslon Eltepe, 2400 m; 9-8-1984 (LM3119).
10. Kazana Tsirkus, 2400 m; 9-8-1983 (LM2703).
11. Ridge between Malkiya and Golemiya Kazan, 2350 m; 9-8-1984 (LM3116).
12. Ridge between Malkiya and Golemiya Kazan, 2400 m; 10-8-1984 (LM3121).
13. Ridge between Malkiya and Golemiya Kazan, 2350 m; 10-8-1984 (LM3122).
14. Golemiya Kazan, 2450 m; 10-8-1984 (LM3126).
15. Golemiya Kazan, 2500 m; 10-8-1984 (LM3131).
16. Tsirkus Kamenititsa, flanks of Bayuvi Dupki Mt., 2750 m; 12-8-1984 (LM3149).

THE FLORISTIC COMPOSITION OF THE SILA GRECA PASTURES (CALABRIA, S - ITALY)

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Keywords: Sila, pastures, vegetation, Calabria (S-Italy).

Abstract. The classification of 28 phytosociological relevés of pasture vegetation from the Ionian slope of the Sila massif (S-Italy) allowed to recognize four main vegetation types. They are: *Hedysarum coronarium* - *Cynara cardunculus* community, *Agrostis castellana* - *Oenanthe pimpinelloides* community, *Vulpia ciliata*-*Trifolium arvense* community and *Potentilla calabra* - *Armeria canescens* community. The indirect gradient analysis based on the reciprocal ordering of relevés and species, and on the ecological evaluation of the species, reveals that the floristical variation is related to both climatic and edaphic factors. The four community - type are well characterized by different structural and phytogeographic features.

Introduction

The pasture vegetation of the Sila plateau has been already studied by Sarfatti (1954), Giacomini & Gentile (1961) and Abbate *et al.* (1984). The pastures of the Ionian slope of the Sila (Sila Greca), however, have never been the object of careful investigations, with the exception of two studies on their structural and phytogeographic variations respectively by Codogno *et al.* (1987) and Codogno & Puntillo (1987). Sila Greca is a region where the cattle grazing is one of the most important human activities and a vegetational study of the pastures in this area can be useful in the re-establishment and management of these natural resources.

The aims of this study are:

- to relate the floristical variation of the pasture vegetation to possible environmental gradients;
- to identify floristically defined pasture types.

Survey area

The survey area is located on the northeastern slope of the Sila massif, between the Cino and Nicà Rivers (Fig. 1). This area is limited at the southern side by a

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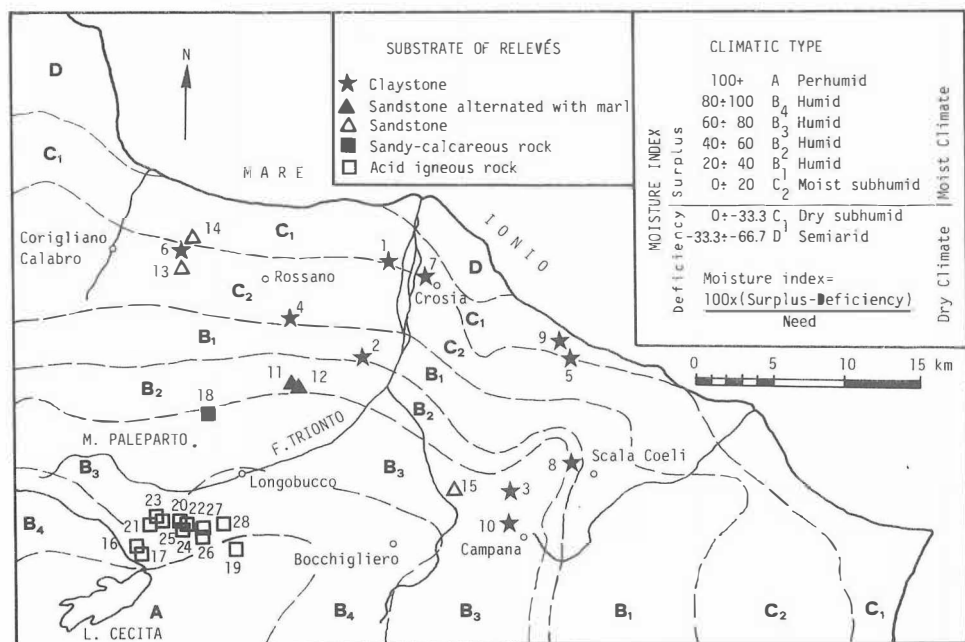


Fig. 1 — Map of the survey area with relevé localities. The climate types are following the Thornthwaite's classification (1948). For each sampling site the substrate type is indicated.

mountain ridge (M. Altare, m. 1653 m; M. Paleparto, 1480 m), that separates the Sila Greca from the Sila Grande, and at the northern side by the Ionian Sea. The altitudinal variation is very sharp (from 1500 m to the sea level in only 20 km) and deep valleys are cut by periodic streams ("fiumare").

The geological substrate is composed by a fairly wide range of rocks (Magri *et al.*, 1963-1965; Ogniben, 1973): igneous rocks (granite), metamorphic rocks (gneiss, schists and phyllites) and sedimentary rocks (sandstones, claystones, limestones, marls, etc.). These different bedrocks have given rise to different soils.

The climate is Mediterranean, with humid winters and dry summers. As far as the degree of humidity is concerned, the climate presents a broad range of variation related to the altitude (Ciancio, 1971): from the semiarid climate of the coast to the perhumid climate of the highest localities (see Fig. 1).

The vegetation is strongly influenced by both the moisture degree (elevation; Codogno & Puntillo, 1988) and the texture of the substrate.

Data and methods

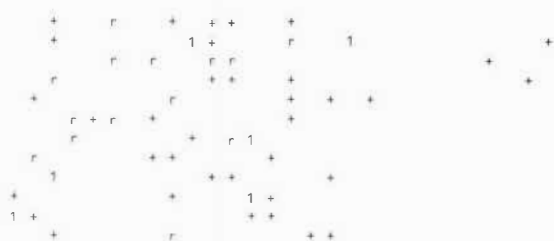
This study is based on a set of 28 phytosociological relevés (Tab. 1), taken with the Braun-Blanquet (1964) method in stations at different elevation (between 0-1500 m) and on different substrates, in order to reflect the broadest possible

Tab. 1 — Structured table of species and relevés. Relevé group numbers are as in the dendrogram of Fig. 2. The species which have not been retained in this table are in the Appendix.

RELEVÉ GROUP No.	1									2			3			4											
Relevé No.	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8
<i>Hedysarum coronarium</i>	2	+	2	2	+	1	3	+	+	3																	
<i>Cichorium intybus</i>	+	r	2	+	r	r	r	+	1	1																	
<i>Cynara cardunculus</i>	1	r	1	+	3	2		+																			
<i>Inula viscosa</i>	r	+	+	1	+	r	r																				
<i>Euphorbia exigua</i>	2	r	+		r	+	1	+																			
<i>Blackstonia perfoliata</i>	r	r	+	r	r	r	r	+	+																		
<i>Bellardia trixago</i>	+	+	+	+	+	+	+	+	r	+																	
<i>Anagallis arvensis</i>	+	r	+	r	r	1	r																				
<i>Linum strictum</i>	r	+	+	+	r	r																					
<i>Scorzonera trachysperma</i>	+	1	1	r	+	+	+	+																			
<i>Ononis alopecuroides</i>			2	1	+	1	1																				
<i>Sonchus oleraceus</i>	+	r	r				r	r																			
<i>Plantago serraria</i>	+	1	1	1			+																				
<i>Bellevalia romana</i>	r	r					1	1																			
<i>Picris echioides</i>	2						+	r	1																		
<i>Pallenis spinosa</i>	r		1	+			r																				
<i>Hypochoeris achyrophorus</i>	+	r				r	+	+																			
<i>Foeniculum vulgare</i>		r				r	+	+																			
<i>Catananche lutea</i>	+	+					+	+																			
<i>Carduus corymbosus</i>	+	+					+																				
<i>Nigella damascena</i>	r	r				r																					
<i>Centaurium maritimum</i>	+		+					r																			
<i>Brachypodium distachyum</i>	+		r	2																							
<i>Avena fatua</i>	+	+				r																					
<i>Gladiolus italicus</i>	r	r				+																					
<i>Polygala monspeliaca</i>	r	+				r																					
<i>Euphorbia helioscopia</i>						+	r	r																			
<i>Sonchus arvensis</i>							+	+																			
<i>Crepis vesicaria</i>						+	1	+																			
<i>Ophrys bertolonii</i>						+	r	+																			
<i>Carex flacca</i>	r	+	+				2	+																			
<i>Tragopogon dubius</i>	+	r	+					1																			
<i>Trifolium lappaceum</i>	+	+	1																								
<i>Aegilops geniculata</i>	+	1	1	+	r	r																					
<i>Scabiosa maritima</i>			r	+	r	+																					
<i>Catapodium rigidum</i>	+	r						r	+	+																	
<i>Centaurium erythraea</i>	+	r	1	1				+	r	+																	
<i>Dactylis hispanica</i>		3			1	1		2	+	1																	
<i>Trifolium pallidum</i>	+		1	1					1	+																	
<i>Dipsacus fullonum</i>								2		r	r																
<i>Potentilla reptans</i>								r		r	r																
<i>Oenanthe pimpinelloides</i>								+	+	+	+																
<i>Centaurea jacea</i>										1	1																
<i>Echium italicum</i>										1	+																
<i>Prunella vulgaris</i>					+					+	+																
<i>Quercus ilex</i> (saplings)										r	r																
<i>Origanum vulgare</i>										r	r																
<i>Agrostis castellana</i>										1	+	+															
<i>Gastridium ventricosum</i>		+	+							+	1	2															
<i>Tolpis virgata</i>										r	r		+														
<i>Lotus angustissimus</i>										r	+	+		+													
<i>Gaudinia fragilis</i>										+	+	+		+	+												
<i>Medicago orbicularis</i>							+			+	+	+		r	+												
<i>Trifolium angustifolium</i>						r				+	1	+	+	r	r												
<i>Hypericum perforatum</i>										+			+	+	+	+	1										
<i>Vulpia ciliata</i>											+						3	1	+	+	+						
<i>Trifolium arvense</i>													1	r	1	2	2		+								
<i>Chondrilla juncea</i>													+	+	+	+											
<i>Silene gallica</i>													+	1	r	+											
<i>Vicia cracca</i>														+	+	+	+	r									

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Medicago hispida
Cynosurus cristatus
Sanguisorba minor
Picris hieracioides
Bromus hordeaceus
Reichardia picroides
Avena barbata
Vicia sativa
Trifolium scabrum
Chrysanthemum segetum
Hedypnois rhagadioloides
Scorpiurus muricatus



ecological variation. The location of the relevés is reported in Fig. 1.

Data analysis occurred in the following steps:

- numerical classification of the relevés, to obtain community - types. The clustering was Complete Linkage based on Correlation Coefficient as similarity measure, using binary data (Anderberg, 1973).

- reciprocal ordering (Orlóci, 1978) of both the relevés and the species, to analyze the floristical variation in the data set, and to detect possible ecological gradients underlying this variation. The reciprocal ordering used cover data, modified according van der Maarel (1979).

In the relevés, 348 species are represented. The high number of species required a size reduction of the data set for the handling with automated methods. For the numerical classification only the species having occurrences in more than one relevé have been retained (218 species). The reciprocal ordering is based only on the species of the characteristic specific combinations of the community - types obtained by classification (143 species) following the approach of Raabe (1950) and Feoli (1975). The latter species have been reported in Tab. 1. The other species are in the Appendix.

Results and discussion

The numerical classification of the relevés produced four main groups (Fig. 2). In Tab. 1 the relevés are ordered according to the dendrogram of Fig. 2. In this table most species are linked only to one (or at most two) relevé group and a clear floristic trend is evident. The ecological significance of this trend results from the indirect gradient analysis based on the reciprocal ordering of relevés and species shown in Fig. 3. In this figure, the compositional gradient (dashed line through the centroids of the relevé groups) can be interpreted as revealing ecological gradients, on the basis of the climatic and edaphic features of the relevé sites (Fig. 2) and of the ecological significance of the species plotted in Fig. 3. From relevé group 1 to group 4 both air moisture (from dry - subhumid to perhumid climate type) and soil texture (from fine - grained soil derived from clay rocks to coarse - grained soil derived from acid igneous rocks) increase. It is noteworthy that in Fig. 3 the second canonical variate separates the relevés taken on abandoned cultivations (groups 2 and 3; acid igneous rocks) increase. It is noteworthy that in Fig. 3 the second canonical variate separates the relevés on abandoned cultivations (groups 2 and 3; negative scores) from the others (positive scores).

On the basis of the structured table of the relevés (Tab. 1) and of the indirect

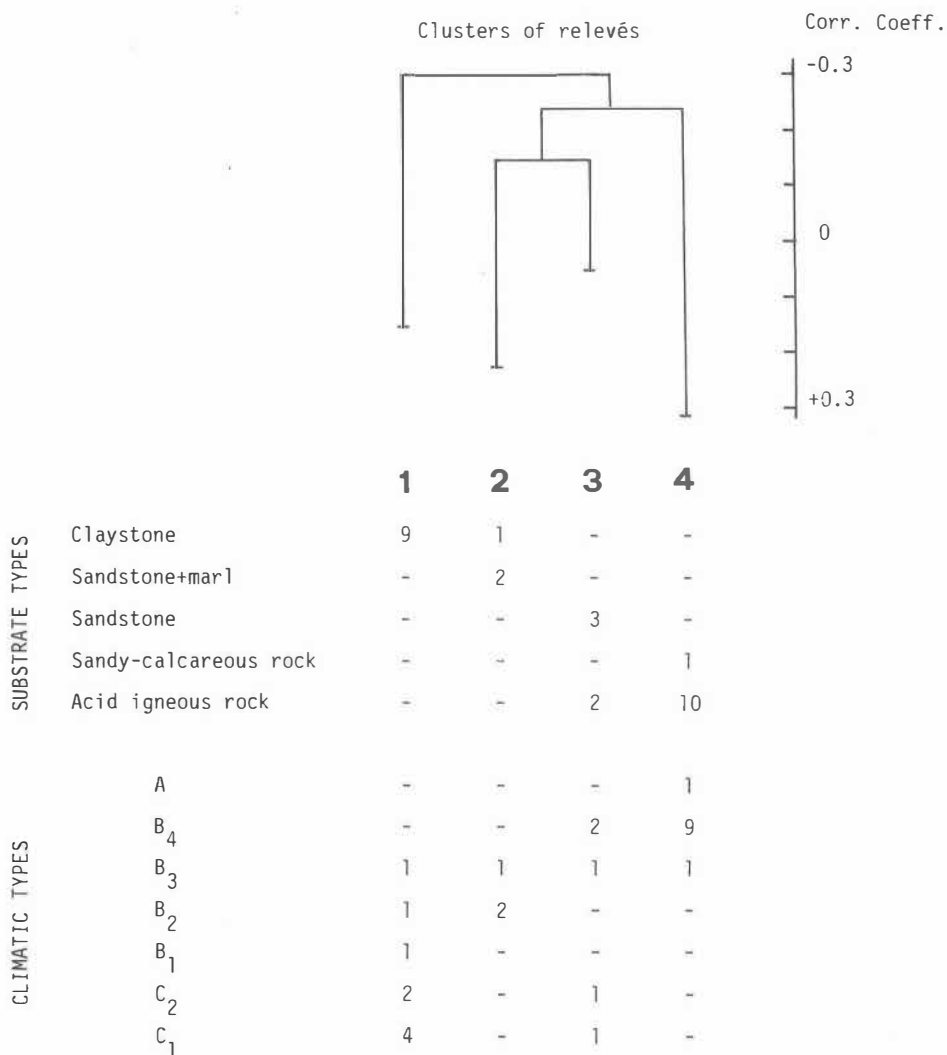


Fig. 2 — Classification of the relevés. The values in this figure are absolute frequencies of relevés occurring in sites with a given climate and substrate type in the four relevé groups.

gradient analysis, the four relevé groups could be considered as ecologically well characterized nodes of the compositional gradient. These nodes have been interpreted as distinct community - types:

Hedysarum coronarium-*Cynara cardunculus* community (Tab. 1, relevé group 1)

Differential species: *Hedysarum coronarium*, *Cynara cardunculus*, *Ononis alopecuroides*, *Scorzonera trachysperma*, *Plantago serraria*, *Brachypodium dista-*

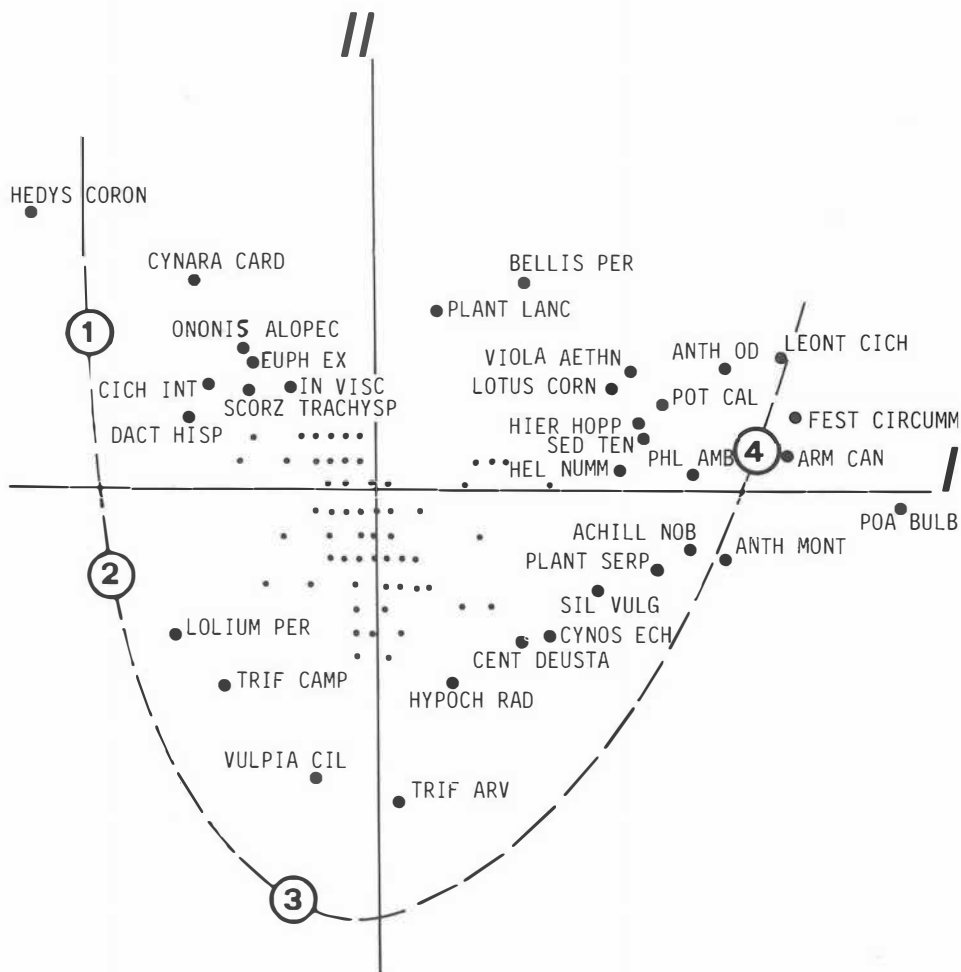


Fig. 3 — Reciprocal ordering of relevés and species. The circled numbers indicate the position of the relevé group centroids as in Fig. 2. Only the names of species characterized by high scores on the first two axis are reported. Further explanations are in the text.

chium, *Bellardia trixago*, *Bellevalia romana*, *Catananche lutea*, *Carduus corymbosus*, *Picris echioides*.

This is a forb formation of sites with clay soil at 200-300 m altitude. Remarkable is the high incidence of perennial species (e.g. *Hedysarum coronarium*, *Cynara cardunculus*, *Scorzonera trachysperma*, *Carduus corymbosus*, *Plantago serraria*). Several species occurring within this community are strictly linked to clay soils (e.g. *Hedysarum coronarium*, *Ononis alopecuroides*, *Carduus corymbosus*, *Catananche lutea*) throughout their ranges.

Relevé 5, with a steppe aspect (high cover values of *Lygeum spartum* and *Cym-*

bopogon hirtus), is similar to the *Lygeum spartum* - prairies described for the clay soils of S - Calabria (Gentile & Di Benedetto, 1961; Schneider & Sutter, 1982) and Basilicata (Zanotti Censoni *et al.*, 1980). Fragments of these prairies are present also in the study area on badlands. The above mentioned authors have placed these formations in the order *Lygeo - Stipetalia*, firstly described for the Ebro valley in NE-Spain (Braun - Blanquet & de Bolos, 1957). The arid climate of this valley explains the massive presence of this semidesert vegetation characterized by some N-African species (*Lygeum spartum*, *Artemisia herba - alba*, *Stipa* sp. pl.) (Walter, 1973). On the contrary, in Calabria, with a moister climate (mean annual precipitation nearly always exceeding 500 mm — Caloiero, 1975), the *Lygeum spartum* - prairies are probably an edaphic formation limited to the clay soils of badlands which are among the driest habitats during the vegetative season.

The *Hedysarum coronarium* - *Cyanara cardunculus* community and the *Lygeo - Stipetalia* vegetation have strong S - Mediterranean affinities (Codogno & Puntillo, 1987), but they are structurally different: in the first community - type perennial species are abundant (35% hemicryptophytes and 14% geophytes — Codogno *et al.*, 1987), whereas the *Lygeo - Stipetalia* vegetation is mainly formed by therophytes (more than 70% in Braun - Blanquet & de Bolos, 1957). The high incidence of perennial species in this community is probably linked to climatic (moisture) and other (cattle - grazing) factors.

Agrostis castellana - *Oenanthe pimpinelloides* community (Tab. 1, relevé group 2)

Differential species: *Agrostis castellana*, *Oenanthe pimpinelloides*, *Echium italicum*, *Gastridium ventricosum*.

This is a forb formation on abandoned cultivation at ca. 700m altitude. The sites are characterized by deep and clay soil. The perennial species still have a high incidence (e.g. *Agrostis castellana*, *Oenanthe pimpinelloides*, *Echium italicum*, *Cynosurus cristatus*, *Dactylis hispanica*). *Lolium perenne* has always high cover values. Several species grow usually on humid substrates (e.g. *Agrostis castellana*, *Oenanthe pimpinelloides*, *Lotus angustissimus*, *Potentilla reptans*, *Gaudinia fragilis*). On the basis of its floristic composition, this community - type is transitional between the previous and the next community - types.

Vulpia ciliata - *Trifolium arvense* community (Tab. 1, relevé group 3)

Differential species: *Vulpia ciliata*, *Trifolium arvense*, *Chondrilla juncea*, *Silene gallica*, *Anthemis arvensis*, *Echium plantagineum*, *Briza maxima*, *Trifolium strictum*, *Jasione echinata*, *Hypericum perforatum*, *Vicia cracca*.

This is a weed formation on abandoned cultivation at an average altitude of 720 m. Ephemeral species are common (e.g. *Vulpia ciliata*, *Trifolium arvense*, *Silene gallica*, *Anthemis arvensis*, *Echium plantagineum*, *Briza maxima*, *Trifolium strictum*). Several species are strictly linked to sandy soils (e.g. *Echium plantagineum*, *Jasione echinata*, *Silene conica*). Most species are therophytes with broad ecological

amplitude: only a few species are characteristic of ephemeral formations on acid soil (*Tuberarietalia guttati*; e.g. *Silene gallica*, *Briza maxima*).

Contrary to the first community type, this formation has a N-Mediterranean phytogeographical affinity (Codogno & Puntillo, 1987). Moreover, remarkable is the "european-continental" character of this community due to the presence of some S-European/S-Siberian species which in the study area occur mainly in this vegetation type (e.g. *Chondrilla juncea*, *Carlina vulgaris*, *Micropus erectus*, *Agrostemma githago*).

Potentilla calabra - *Armeria canescens* community (Tab. 1, relevé group 4)

Differential species: *Potentilla calabra*, *Armeria canescens*, *Festuca circummediterranea*, *Helianthemum nummularium*, *Hieracium hoppeanum*, *Sedum tenuifolium*, *Bunium bulbocastanum*, *Thymus pulegioides*, *Hypericum barbatum*, *Leontodon cichoraceus*, *Plantago serpentina*, *Petrorhagia saxifraga*, *Anthoxanthum odoratum*, *Phleum ambiguum*.

This is a montane grassland formation of sites characterized by sandy soils at an average altitude of 1460 m. Perennial species are most common (ca. 90%, see Codogno *et al.*, 1987; e.g. all the differential species). Chamaephytes have a high incidence (e.g. *Helianthemum nummularium*, *Thymus pulegioides*, *Sedum tenuifolium*). Several species occurring in this community are characteristic of prairies on acid sandy soil (*Sedo - Scleranthetea*; e.g. *Plantago serpentina*, *Petrorhagia saxifraga*, *Sedum tenuifolium*). *Potentilla calabra* belongs to the *Potentilla argentea*-group which is characteristic of the class *Sedo - Scleranthetea*. This vegetation type characterizes the pastures of the Sila plateau (Abbate *et al.*, 1984), Aspromonte (Schneider & Sutter, 1982) and similar communities occur also in Sicily on Nebrodi (Brullo & Grillo, 1978) and Madonie (Brullo, 1983). The phytosociology of these formations needs to be supported by more field data from all the W- and central-Mediterranean basin.

This vegetation type is characterized by the presence of several Mediterranean and S-European orophytes. Moreover, it is remarkable the coexistence of W-European (e.g. *Bunium bulbocastanum*) and SE-European species (e.g. *Hypericum barbatum*, *Potentilla calabra*) (Codogno & Puntillo, 1987). This reflects the situation of the thorny - cushion associations of the Sila, where *Astragalus calabrus* (with eastern origin) and *Genista anglica* (with W-European origin) coexist in the same altitudinal (montane) belt. Probably, the different historical - genetical factors that have influenced the thorny - cushion associations (Nimis, 1981) had an influence also on the *Potentilla calabra*-*Armeria canescens* community.

Appendix

Species which have not been retained in Tab. 1:

In 5 relevés: *Ranunculus neapolitanus* (2, 10, 20, 22, 24).

In 4 relevés: *Ranunculus bulbosus* (13, 22, 24, 28).

In 3 relevés: *Trifolium physodes* (3, 9, 10), *Prunella laciniata* (3, 10, 14); *Serapias vomeracea* (5, 8, 10); *Trifolium stellatum* (6, 9, 13); *Galactites tomentosa* (6, 9, 14); *Ranunculus ficaria* (6, 27, 28); *Ranunculus millefoliatus* (7, 26, 27); *Juncus bufonius* (8, 9, 14); *Cytisus scoparius* (8, 23, 25); *Ranunculus flabellatus* (8, 27, 28); *Galium murale* (17, 22, 23); *Malva moschata* (18, 19, 27); *Trifolium repens* (18, 23, 28); *Veronica acinifolia* (20, 22, 24); *Scleranthus polycarpus* (20, 24, 27); *Astragalus glycyphyllos* (22, 23, 27); *Luzula campestris* (26, 27, 28).

In 2 relevés: *Torilis nodosa* (1, 2); *Trifolium congestum* (1, 2); *Tetragonolobus purpureus* (1, 6); *Lythrum junceum* (1, 6); *Ammi majus* (1, 9); *Beta vulgaris* subsp. *maritima* (1, 9); *Medicago rigidula* (1, 12); *Carthamus lanatus* (1, 14); *Calamintha nepeta* (1, 15); *Ammoides pusilla* (1, 15); *Scabiosa columbaria* (1, 15); *Cardopatum corymbosum* (2, 5); *Lotus ornithopodioides* (2, 7); *Kundmannia sicula* (2, 14); *Allium ampeloprasum* (2, 14); *Lophochloa cristata* (2, 14); *Bromus madritensis* (2, 16); *Melilotus sulcata* (3, 4); *Carlina lanata* (3, 6); *Ononis spinosa* (3, 10); *Medicago lupulina* (3, 13); *Asphodelus microcarpus* (4, 5); *Ophrys lutea* (5, 7); *Pistacia lentiscus* pl. (5, 7); *Allium roseum* (5, 7); *Orchis italica* (5, 8); *Cirsium arvense* (5, 9); *Daucus carota* subsp. *maritimus* (5, 9); *Tragopogon porrifolius* (5, 15); *Salvia pratensis* (6, 10); *Urospermum picroides* (7, 9); *Carduncellus coeruleus* (8, 10); *Orchis laxiflora* (8, 10); *Ornithopus compressus* (8, 10); *Calendula arvensis* (9, 14); *Centaurea napifolia* (9, 15); *Cynoglossum creticum* (9, 20); *Bromus scoparius* (10, 14); *Briza minor* (10, 14); *Rumex pulcher* (10, 15); *Linum bienne* (10, 21); *Poa trivialis* (10, 23); *Pinus laricio* pl. (11, 27); *Hypochoeris glabra* (12, 13); *Lolium rigidum* (14, 19); *Rumex acetosa* (14, 20); *Carlina utzka* (17, 26); *Vicia villosa* (20, 22); *Silene paradoxa* (22, 23); *Acinos alpinus* (22, 24); *Rubus idaeus* (22, 24); *Carlina acaulis* (23, 28); *Scilla bifolia* (26, 27); *Doronicum orientale* (27, 28).

In 1 relevé: *Lavatera cretica* (1); *Phalaris brachystachys* (1); *Sideritis romana* (1); *Filago pyramidata* (1); *Phalaris paradoxa* (1); *Melampyrum arvense* (1); *Bromus gussonei* (1); *Ornithogalum pyramidale* (1); *Ononis natrix* (1); *Althaea cannabina* (1); *Ornithogalum pyrenaicum* (2); *Phalaris coerulescens* (2); *Phleum pratense* (3); *Plantago bellardi* (3); *Medicago murex* (3); *Parentucellia latifolia* (3); *Phalaris truncata* (4); *Malope malacoides* (4); *Lygeum spartum* (5); *Cymbopogon hirtus* (5); *Ophrys bombyliflora* (5); *Iris sisyrinchium* (5); *Urginea maritima* (5); *Hedysarum glomeratum* (5); *Evax pygmaea* (5); *Bellis annua* (5); *Anemone hortensis* (6); *Atractylis cancellata* (6); *Plantago media* (6); *Hymenocarpus circinnatus* (6); *Scorzonera humilis* (6); *Allium subhirsutum* (6); *Crupina crupinastrum* (6); *Asphodeline lutea* (7); *Borago officinalis* (7); *Asparagus acutifolius* (7); *Asphodelus albus* (7); *Theligionum cynocrambe* (7); *Anthyllis tetraphylla* (7); *Filago germanica* (7); *Prunus spinosa* pl. (7); *Pastinaca sativa* (8); *Ophrys tenthredinifera* (8); *Arundo pliniana* (8); *Serapias neglecta* (8); *Salvia verbenaca* (8); *Mentha longifolia* (8); *Agrimonia eupatoria* (8); *Eryngium campestre* (8); *Urospermum dalechampii* (8); *Phlomis ferruginea* (8); *Rumex crispus* (9); *Glycyrrhiza glabra* (9); *Medicago sativa* (9); *Verbascum sinuatum* (9); *Vicia lutea* (9); *Melilotus indica* (10); *Anacamptis pyramidalis* (10); *Orchis coriophora* var. *fragrans* (10); *Cynodon dactylon* (11); *Linum tryginum* (12); *Echium vulgare* (12); *Cistus monspeliensis* (13); *Andryala integrifolia*

(13); *Rumex bucephalophorus* (13); *Bunias erucago* (13); *Erodium cicutarium* (13); *Tuberaria guttata* (13); *Allium tenuiflorum* (13); *Capsella bursa-pastoris* (14); *Papaver hybridum* (14); *Medicago arabica* (14); *Plantago psyllium* (14); *Cyperus rotundus* (14); *Secale cereale* (14); *Phleum subulatum* (14); *Polycarpon tetraphyllum* (14); *Stachys arvensis* (14); *Sisymbrium officinale* (14); *Trisetaria panicea* (14); *Juncus capitatus* (14); *Polygonum aviculare* (14); *Valerianella microcarpa* (14); *Trifolium tomentosum* (14); *Hordeum leporinum* (14); *Dasypyrum villosum* (14); *Aegilops triuncialis* (14); *Cerastium glomeratum* (14); *Lathyrus cicera* (14); *Bromus tectorum* (14); *Myosotis arvensis* (14); *Juncus ambiguus* (14); *Trifolium glomeratum* (14); *Knautia integrifolia* (15); *Odontites serotina* (15); *Cynosurus elegans* (15); *Lathyrus hirsutus* (15); *Pimpinella peregrina* (15); *Kickxia spuria* (15); *Crepis zacintha* (15); *Helichrysum italicum* (15); *Carex divulsa* (15); *Dianthus carthusianorum* (16); *Petrorhagia prolifera* (16); *Secale strictum* (16); *Crepis neglecta* (17); *Papaver dubium* (17); *Alyssum montanum* (17); *Epilobium tetragonum* (17); *Onopordum illyricum* (17); *Agrostemma githago* (17); *Dianthus vulturius* (18); *Clinopodium vulgare* (18); *Cerastium brachypetalum* (19); *Poa pratensis* (20); *Alopecurus geniculatus* (20); *Smyrniium perfoliatum* (20); *Crepis biennis* (20); *Achillea millefolium* (20); *Ornithogalum umbellatum* (21); *Geranium pusillum* (22); *Prunus cocomilia* pl. (23); *Crocus albiflorus* (26); *Silene behen* (27); *Trifolium pratense* (28); *Cerastium luridum* (28); *Bromus erectus* (28); *Sedum reflexum* (28); *Cruciata laevipes* (28); *Lychnis flos-cuculi* (28).

Nomenclature follows Pignatti (1982).

Riassunto

Sono stati eseguiti 28 rilievi fitosociologici nei pascoli del versante ionico della Sila (Italia meridionale). La classificazione numerica dei rilievi basata sulla composizione floristica ha messo in evidenza l'esistenza di quattro tipi principali di vegetazione: cenosi a *Hedysarum coronarium*-*Cynara cardunculus*, cenosi ad *Agrostis castellana*-*Oenanthe pimpinelloides*, cenosi a *Vulpia ciliata*-*Trifolium arvense* e cenosi a *Potentilla calabra*-*Armeria canescens*. L'analisi indiretta di gradiente basata sull'ordinamento reciproco dei rilievi e delle specie e sulla valutazione ecologica delle specie ha evidenziato che la variazione floristica è legata a differenze sia climatiche che edafiche all'interno dell'area di studio. Inoltre i quattro tipi di fitocenosi sono risultati essere ben caratterizzati da strutture ed affinità fitogeografiche diverse.

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ON THE WAYS OF EXPRESSING RADIOCESIUM CONTAMINATION IN PLANTS FOR RADIOECOLOGICAL RESEARCH

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Keywords: Cesium - 137, Potassium - 40, Radiocontamination, Radioecology.

Abstract: In vascular plants radiocesium and K-40 are mostly free in aqueous solution. The expression of radiocontamination on dry weight basis does not take into account the fact that different plant species, or different parts of a species, may have very different contents in cellulose or lignine. These may mask the actual concentration of the radionuclides in plant water, a fact that may be a serious source of error when the aim is to compare absorption rates. This paper, on the basis of a case study on 10 species in the Carnic Alps (NE-Italy), shows how the expression of radiocontamination on a water basis (difference between fresh and dry weight) may be much more appropriate in certain fields of radioecological research.

Introduction

All the alkali metal ions are readily absorbed by plants. According to Collander (1941), potassium, rubidium and cesium are the most copiously accumulated by plants. There is evidence of an antagonism between potassium and cesium in their absorption and accumulation by plants; Menzel (1954), using radioisotopes, found the uptake of rubidium and cesium from soil to be inversely proportional to the available potassium. An antagonistic behaviour on the two ions has been demonstrated also by Middleton (1960), Jackson et al. (1966) and Andersen (1967).

Potassium, probably the most important macronutrient cation, the most mobile in the plant and essential to every cell, has an anion-balancing role as well as a specific function. In its anion-balancing role it is partially replaceable by other elements, particularly by rubidium and cesium (Epstein & Hagen, 1956), which might be related to their antagonistic behaviour. There is evidence that almost all the potassium present in the plants appears free in aqueous solution on extraction and probably also in the intact cell (Robertson, 1958). Given the great chemical similarity between potassium and cesium, this probably holds true also for the latter.

In the greatest majority of the studies dealing with radioprotection or radioecology, the contamination of plant material by radiocesium is expressed on a dry or fresh weight basis. This means that the quantity of dead plant material present in a

sample (cellulose, lignine etc.) has a great influence on the measurement. In our opinion, this fact may be particularly disturbing in certain fields of radioecology, since it introduces a consistent source of noise in the evaluation of the actual concentration of radiocesium in plant water (cytoplasmatic and apoplastic solutions), where most of the radiocesium is expected to be located.

Aim of this paper is to compare, on a limited data set, two ways of expressing the radiocontamination of plant material: a) on dry weight basis (Bq/kg), b) on a water-basis (Bq/l), and to discuss the advantages of the latter for the solution of certain radioecological problems.

Tab. 1 — Dry weight, percent of water, water weight and depth of the root systems of the 10 species analyzed in this study.

		Dry weight (g)	water (%)	water weight (g)	Depth (cm)
<i>Acer pseudo-platanus</i>	Leaves	4.83	69.6	11.1	20 - 25
	Stems	17.78	51.8	19.0	
	Roots	26.58	51.7	28.4	
<i>Adenostyles alpina</i>	Leaves	8.85	87.1	60.1	20 - 25
	Stems	11.82	93.1	159.6	
	Roots	28.75	71.8	73.3	
<i>Anemone trifolia</i>	Leaves	4.59	81.6	20.4	6 - 7
	Stems	4.49	81.4	19.7	
	Rhizomes	18.44	72.2	47.9	
<i>Fagus sylvatica</i>	Leaves	8.41	64.8	15.5	5
	Stems	24.37	43.4	18.5	
<i>Oxalis acetosella</i>	Leaves	2.67	87.9	19.4	1
	Rhizomes	7.33	74.1	21	
<i>Polygonatum verticillatum</i>	Leaves	4.47	86.1	27.6	6 - 7
	Stems	9.42	86.3	59.2	
	Rhizomes	14.11	75.5	43.4	
<i>Rosa pendulina</i>	Leaves	6.02	63.1	10.3	6 - 7
	Stems	15.51	40.6	10.6	
	Roots	19.16	37.8	11.7	
<i>Rubus saxatilis</i>	Leaves	3.3	75.7	10.3	2 - 6
	Stems	11.43	78.5	41.7	
	Rhiz. + Roots	24.74	60.7	38.1	
<i>Sorbus aria</i>	Leaves	7.39	71.5	18.6	15
	Stems	17.9	44.7	14.5	
	Roots	25.26	44.9	20.5	
<i>Vaccinium myrtillus</i>	Leaves	4.74	66.7	9.48	1 - 2
	Green stems	14.74	57.4	19.9	
	Lign. stems	25.64	47.4	23.1	
	Rhiz. + Roots	28.66	37.1	16.9	

Data and Methods

The plant samples have been collected at the Pura Pass (Carnic Alps, Province of Udine), in a relatively undisturbed *Fagus-Abies* mixed wood, at 1450 m, on July, 3, 1987, two days after a rain period. The list of all vascular plants occurring in the stand is in Nimis et al. (1986). For each species, leaves, stems, roots and, when present, rhizomes, were collected from at least 10 different individuals. The depth of roots and rhizomes was measured for each single plant. The following species have been sampled: *Acer pseudo-platanus*, *Adenostyles alpina*, *Anemone trifolia*,

Tab. 2 — Contaminations by Cs-137 and K-40 in the different plant parts, expressed in Bq/kg and Bq/l.

		Cs - 137		K - 40	
		Bq/kg	Bq/l	Bq/kg	Bq/l
<i>Acer pseudo-platanus</i>	Leaves	137	60	786	342
	Stems	54	51	145	135
	Roots	60	56	139	130
<i>Adenostyles alpina</i>	Leaves	127	19	1325	195
	Stems	239	18	1595	118
	Roots	290	114	309	121
<i>Anemone trifolia</i>	Leaves	295	66	336	76
	Stems	605	138	1712	390
	Rhizomes	240	92	243	94
<i>Fagus sylvatica</i>	Leaves	346	188	623	338
	Stems	150	198	170	225
<i>Oxalis acetosella</i>	Leaves	1046	144	1177	162
	Rhizomes	1796	627	662	231
<i>Polygonatum verticillatum</i>	Leaves	190	31	674	109
	Stems	101	16	850	135
	Rhizomes	86	28	393	128
<i>Rosa pendulina</i>	Leaves	272	155	475	277
	Stems	87	129	123	181
	Roots	47	81	155	253
<i>Rubus saxatilis</i>	Leaves	440	141	835	267
	Stems	353	97	469	128
	Rhiz. + Roots	325	211	195	127
<i>Sorbus aria</i>	Leaves	178	71	471	187
	Stems	55	68	133	165
	Roots	35	49	145	178
<i>Vaccinium myrtillus</i>	Leaves	545	272	594	297
	Green stems	459	340	329	244
	Lign. stems	233	259	32	36
	Rhiz. + Roots	232	393	105	178

Fagus sylvatica (saplings), *Oxalis acetosella*, *Polygonatum verticillatum*, *Rosa pendulina*, *Rubus saxatilis*, *Sorbus aria*, *Vaccinium myrtillus*. The list of all plant samples (altogether 29), their water content, and the depth of the root systems are reported in Tab. 1.

The samples have been weighted immediately after collecting; they were subsequently dried and grinded to utilize the best possible geometry of measurement. The activity of the samples has been measured by a solid state detector, which is an intrinsic Germanium of the Tennenec with inserted pre-amplifier, cooled with liquid nitrogen and protected from natural radiation by a 40 cm thick lead layer. Its main characteristics are: FW HM at 1.33 MeV - 11.88 KeV, relative efficiency: 18%, active volume: 83 cm³, useful surface: 19 cm²; it is connected with an Ortec amplifier mod. 578. The multichannel is a XT IBM calculator with dedicated software Nucleus. The measurement time ranged between 600 and 32.000 seconds, depending on the activity of the sample. The minimal detectable activity ranges between 10 and 100 Bq/kg of dry weight, depending on the volume of the sample. The activity of the samples, concerning Cs-137 and K-40, has been expressed both

Tab. 3 — Average contaminations of the 10 species by Cs-137 and K-40, expressed in Bq/kg and Bq/l, and standard deviations.

		Cs - 137		K - 40	
		Bq/kg	Bq/l	Bq/kg	Bq/l
Acer pseudo - platanus	average	84	56	357	202
	Std. dev.	46	4	372	121
Adenostyles alpina	average	219	50	1076	145
	Std. dev.	83	55	678	44
Anemone trifolia	average	380	99	764	187
	Std. dev.	197	36	823	176
Fagus sylvatica	average	248	193	396	281
	Std. dev.	139	7	320	80
Oxalis acetosella	average	1421	385	919	196
	Std. dev.	530	341	364	49
Polygonatum verticillatum	average	127	25	639	124
	Std. dev.	56	8	231	13
Rosa pendulina	average	133	122	251	237
	Std. dev.	140	37	195	50
Rubus saxatilis	average	373	150	500	171
	Std. dev.	60	57	321	81
Sorbus aria	average	89	63	250	177
	Std. dev.	77	12	192	11
Vaccinium myrtillus	average	367	316	265	189
	Std. dev.	159	62	253	113

on dry weight basis (Bq·kg) and on water basis (Bq·l); in the latter case it is expressed on the difference between fresh and dry weight, i.e. on the total water content of the samples.

Results

The specific activities of the 29 plant samples, relative to Cs-137 and K-40, expressed on dry weight basis and on water basis are reported in Tab. 2. The average values for each species and the standard deviations are shown in Tab. 3.

The average contamination values of leaves, stems and roots of all plants, expressed on dry weight and on water basis are compared in Fig. 1 (a and b). The dry weight-data would suggest a statistically significant contamination difference between leaves and roots, the stems holding an intermediate position. The data expressed on water basis, on the contrary, do not support such a conclusion, and suggest that radiocesium and K-40 are equally distributed in all plant parts. This is well in accordance with the high mobility of these radionuclides in the plant tissues (Coughtrey & Thorne, 1983). In plants the average content in dead plant material (cellulose, lignine etc.) generally decreases from leaves to roots. If we accept the hypothesis that the majority of cesium, in analogy to potassium, is located in the cytoplasmatic solution, it follows that the "contamination" values expressed on dry weight give a false estimate of the actual concentration of Cs-137 in the various plant parts. This may be particularly intriguing for radioecological purposes, when the aim is comparing the absorption rates from the soil of different plants, growing in comparable ecological conditions. For example, *Vaccinium myrtillus* and *Oxalis acetosella* are both acidophytic plants with superficial roots. In the study area the concentration of Cs-137 is maximal in the upper soil horizon (Nimis et al. 1988): if the two plants would show very different contamination values one should have to search for species-specific physiological mechanisms of differential absorption. In our case, the average contamination of *Oxalis* plants, when expressed on dry weight, is ca. four times higher than in the plants of *Vaccinium*. However, one should consider that *Vaccinium myrtillus*, a typical peinomorphic plant has an average water content of only 51% (80% in *Oxalis*). This is reflected in the contamination values expressed on water basis, where the difference between the two species is very slight, and does not justify the search for different physiological mechanisms.

Fig. 2 shows the relation between average depth of the root system and average contamination of the plants analyzed in this study (expressed on water basis). The contamination by Cs-137 shows a clear correlation with depth, which is probably related to the distribution pattern of Cs-137 in the soil profile; this radioisotope is concentrated in the upper soil horizons as a consequence of a recent, intense deposition (the Tchernobyl accident). On the contrary, the concentrations of K-40 are more or less constant, which reflects the uniform distribution of this natural radionuclide in the soils. With data expressed on dry weight no statistically significant correlation with the depth of the root systems has been found for Cs-137, and the values relative to K-40 are far from being constant (see data in Tab. 3).

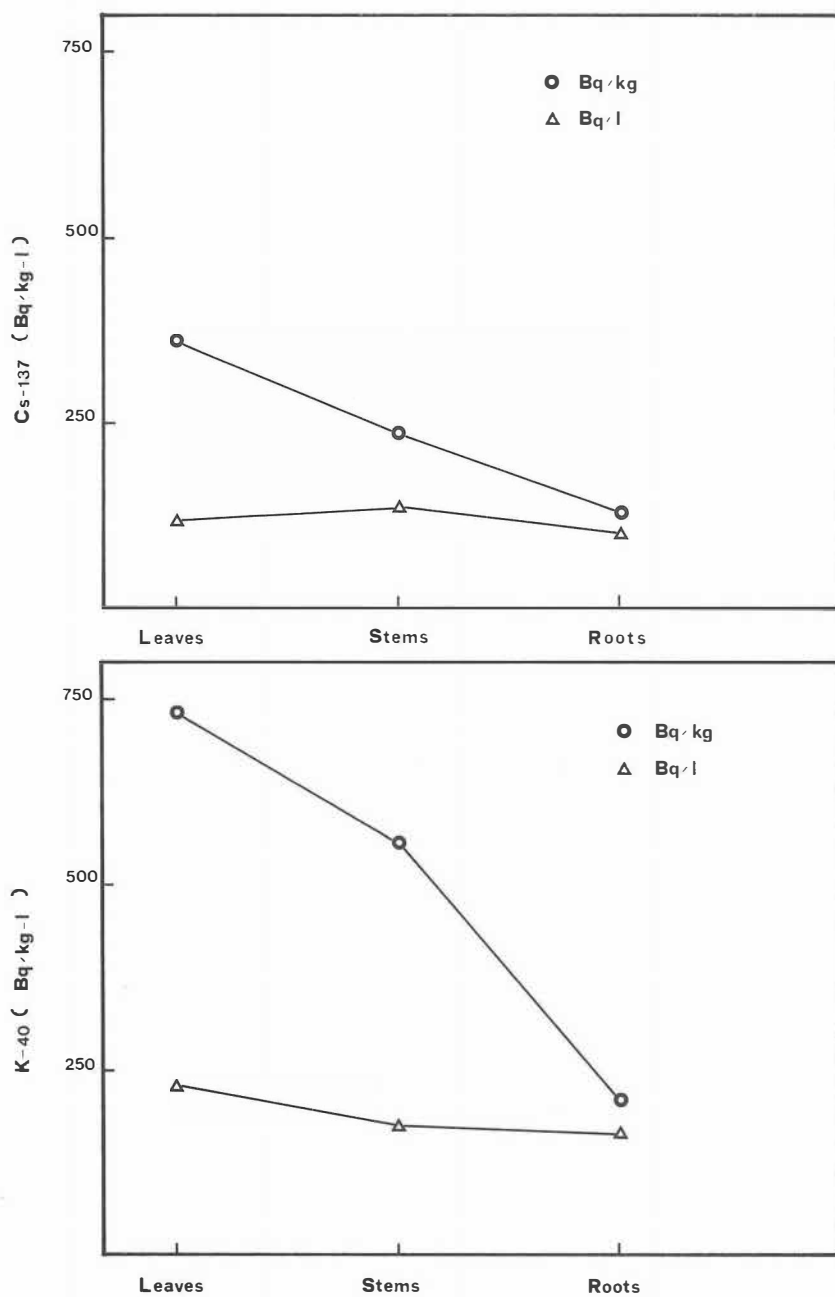


Fig. 1 — Average contaminations of leaves, stems and roots of the 10 species analyzed in this study, expressed in Bq/kg (dry weight) and in Bq/l. a) contamination by Cs-137, b) contamination by K-40.

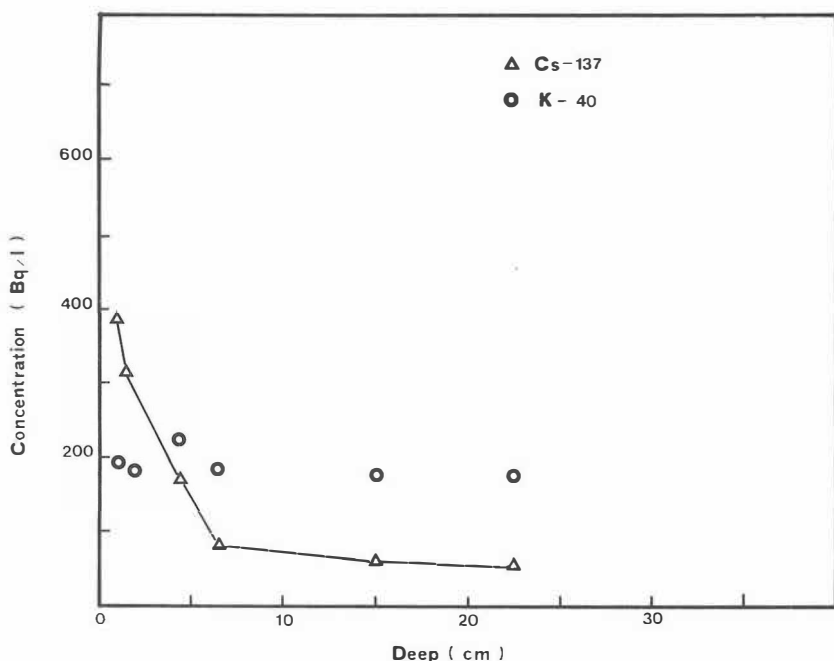


Fig. 2 — Relation between average contaminations by Cs-137 (triangles) and K-40 (circles), and depth of the root systems. The values relative to plants whose roots are at the same depth have been averaged.

Another example of the different results brought about by the two types of data is shown in Fig. 3a, b, which report the relations between average contaminations of Cs-137 and K-40 expressed, respectively, on dry weight basis (Fig. 3a) and on water basis (Fig. 3 b). In the latter case the data indicate that the K-40 content in the plants tends to remain constant in respect with cesium contamination. The data expressed on dry weight, on the contrary, appear much more confused, and do not show any clear relation between the two radioisotopes. The constant values of K-40 in plant material are in agreement with the fact that this radioisotope, being of natural origin, is uniformly distributed throughout the soil profile (see Fig. 2).

Conclusions

These results suggest that radiocontamination by radiocesium and K-40 in plants, when expressed on dry weight, is likely to be burdened by a high degree of distortions. This is due on first line to the varying amounts of cellulose and lignine in different plant species, or in different parts of the same species, which may mask the actual concentration of these radionuclides in plant water. Such a fact may be of little importance in most radioprotection studies, but becomes a serious source of error in certain types of radioecological research, above all when the aim is to

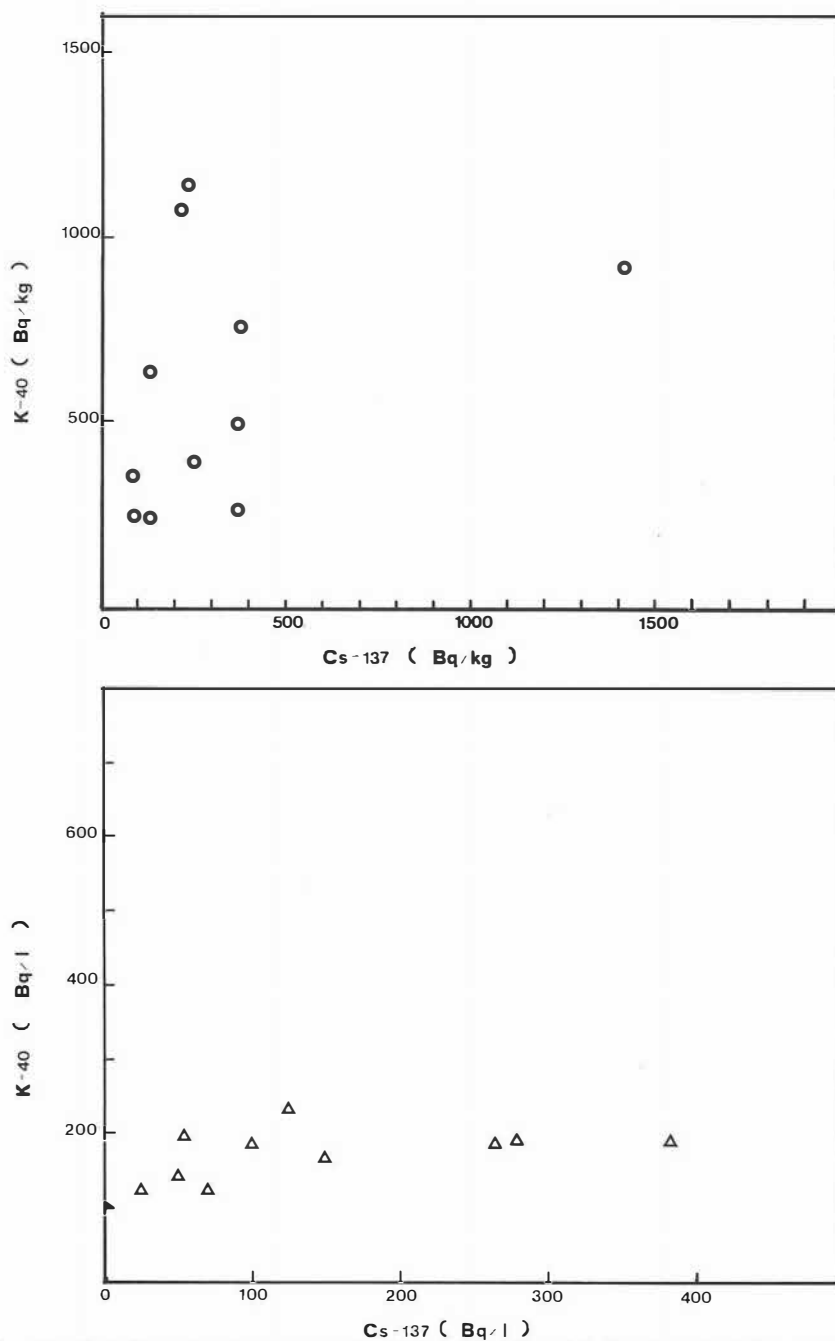


Fig. 3 — Relations between average contaminations by Cs-137 and K-40 in the 10 species, expressed in a) Bq/kg (dry weight), b) Bq/l.

compare the absorption rates of different species. In such cases, contamination expressed on a water basis is suggested as a better tool for plant radioecology.

The difference between fresh and dry weight must be considered just as a first, rough estimate on which to express radiocontamination: the hydration state of vascular plants is subject to variation, and this kind of estimate does not differentiate between cytoplasmatic and apoplastic water. However, it has the advantage of reflecting with a far greater degree of accuracy the concentrations of the radioisotopes in plant water, and, consequently, the actual absorption rates. Obviously, this does not apply to most macrofungi and lichens: however, on the basis of the previous considerations, one should consider how much of the "accumulation" power frequently attributed to these organisms is a real fact, or an artefact due to their complete lack of lignified parts.

Riassunto

La maggior parte del potassio e del cesio presenti nelle piante vascolari sono sotto forma di cationi liberi in soluzione acquosa, sia nell'apo- che nel simplasto. Nella maggior parte degli studi di radioprotezione o radioecologia la contaminazione del materiale vegetale da parte del radiocesio viene espressa in Bq/kg di peso fresco, o secco. Questo tipo di espressione non tiene conto del fatto che differenti specie, o diverse parti della stessa specie, possono avere un contenuto molto diverso di cellulosa o di lignina, che maschera la reale concentrazione del radiocesio in soluzione. Ciò può essere fonte di errori considerevoli soprattutto in studi di radioecologia vegetale, dove lo scopo sia quello di comparare i tassi di assorbimento dal suolo da parte di diverse piante.

Nel presente lavoro vengono paragonati dati di radiocontaminazione da cesio e K-40, in foglie, fusti ed apparati ipogei di 10 specie raccolte in un bosco misto di Abete e Faggio delle Alpi Carniche. I dati sono espressi sia in Bq/kg di peso secco, sia in Bq/l; in quest'ultimo caso l'attività dei campioni è riferita alla differenza tra il loro peso fresco e quello secco, e cioè al loro tenore in acqua. Le misure in Bq/kg suggeriscono una contaminazione crescente dalle foglie alle radici, mentre quelle in Bq/l mostrano una sostanziale equidistribuzione dei due radionuclidi nelle varie parti della pianta. Di fatto, il primo tipo di misura è inficiato dal maggior contenuto di cellulosa e lignina delle radici rispetto alle foglie. Con dati espressi in Bq/l è possibile evidenziare una correlazione negativa significativa tra profondità dell'apparato radicale e contaminazione da Cs-137, mentre il K-40 risulta quasi costante nei tessuti vegetali, indipendentemente dalla profondità delle radici. I dati espressi in Bq/kg risultano molto più confusi e non permettono di trarre alcuna conclusione statisticamente significativa.

Con dati espressi in Bq/l è possibile dimostrare come il K-40 nei tessuti vegetali mantenga valori molto uniformi rispetto a quelli del radiocesio. Anche in questo caso i dati espressi in Bq/kg non permettono di trarre alcuna conclusione significativa.

L'espressione della contaminazione da radiocesio in Bq/l viene suggerita come più appropriata in alcuni campi della radioecologia vegetale.

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CHERNOBYL RADIOISOTOPES IN MACROMICETES IN THE SURROUNDINGS OF COMO LAKES AND OTHER SITES.

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Keywords: Chernobyl, Fungi, Radioactivity, Lombardy

Abstract: The study is based on the measure of the Cs-134, Cs-137 content in samples belonging to species of macromicetes, collected in 13 Stations in Lombardy and in Trentino; most samples have been collected in autumn 1986; a number of samples has been collected in autumn 1987 and 1988.

Significant differences in contamination are recorded both among species collected in the same station, and among average values of the stations themselves.

The differences among stations are tentatively correlated with the amount of precipitations in the days following the Chernobyl disaster. Comparison is made among the 1986 data and the data of the following years.

In many samples the presence of Ag-110 (metastable) is evidenced; the concentration of K-40 naturally occurring radioisotope is measured for most samples.

A brief discussion of the results is presented.

Foreword

A number of authors have studied the dispersion of radioisotopes in north Italian territory, following the accident in the atomic power station at Chernobyl, Ukraine. (Facchini et al. 1987).

The radioactive cloud reached the eastern North Italian regions on april, 29 th 1986, and spread over the alpine valleys and in the Po plain in the early days of may. In a few days the cloud was dispersed by the winds and washed out by the rain. Radioisotopes reached the ground either by the dry deposition mechanism or by the wash out due to the rain. The dry deposition is related, with the aerosol diameter, with the status of the ground: so we find a more intense fall-out on the grassy ground and in the woody land, but a faible one in the stony grounds.

The rains wash out the aerosols in a large space up to the clouds height.

Rain was very intense over the alpine chain and particularly in eastern Friuli, in Lombardy and Piedmont, around the Lakes territory.

The fall out composition is pratically the same over a large territory, over the Alps and in the plain: the composition of radioisotope fall out is reported in Table I.

Table I — Composition of fall-out; Cs-137 = 1

Zr + Nb - 95 0.064	Ru - 103 1.64	Ru - 106 0.41	Ag - 110 0.011	Sb - 125 0.048	I - 131 4.15
Te + I - 132 4.51	Cs - 134 0.46	Cs - 137 1	Ba + La - 140 0.89		

The purpose of the present paper is the analysis of the radioisotope levels, mostly Cs-137 and Cs- 134, in the macromicetes.

A wide analysis of the macromicetes has been done by Nimis et al. (1986) in many stations the woody lands of Friuli; the results show strong differences in the Cesium levels either related to the territory but also to the different mushroom families.

The present analysis is referred to macromicetes collected in the territories around the Lake of Como and the Lago Maggiore and a few other sites; most samples are collected in the autumn 1986, a few months after the Chernobyl accident; other samples are collected in autumn 1987 and 1988. The work results from the collaboration of three Institutes:

- samples around the Como lake and Valtellina are collected by the Circolo Micologico Lariano Plinio il Vecchio and analysed by the Institute of Applied Physics of the Milan University;
- samples in the Como territories and in the Groane, north of Milan are collected by the Unità Sanitarie Locali and examined by the Presidio Multinazionale Igiene Prevenzione;
- samples collected around the Lago Maggiore are due to the Servizio Radioprotezione of the Joint Research Center of Ispra and there analysed;
- finally a few samples are collected by one of the authors (M.G.) in Piné di Trento.

The samples and the measurements

The mushrooms, generally a few samples of the same species, are homogenized and put in special containers: the fresh quantity is around of 1 kg.

The analysis of the radioisotopes is made through the gamma spectrometer.

Different installations for gamma spectra, all based on Germanium devices, are used by the operating groups; the spectrometers have been calibrated and intercalibrated.

The levels of Cs-134 and Cs-137 are detected when the concentration is above a few Becquerel/kg fresh.

Other radioisotopes as Ag-110 (metastable state) have been evidenced in a few samples; in all mushroom samples there is evidence of Potassium and the radioactive K-40 has been measured in most cases.

The ratio Cs-137/K-40, referring both radioisotopes in Becquerel/kg, is then obtained.

The data are given separately for each operating group, and for each station.

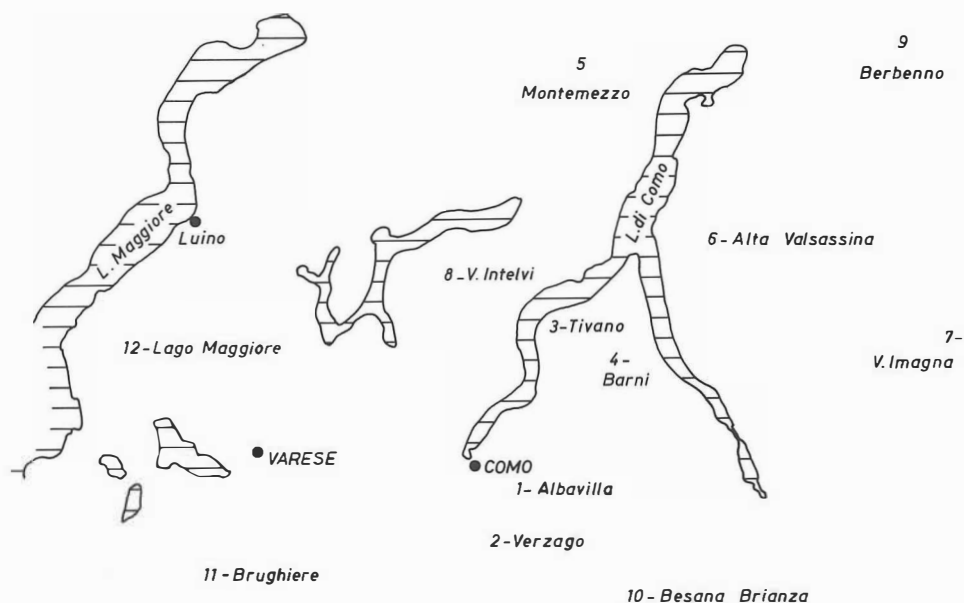


Fig. 1 — Map of Stations

The stations are in Table II, where the characteristic of the sites are also briefly indicated; in Figure 1 we report a map showing the sampling areas in Lombardy.

Table II - Stations.

Station n.	1 Hills around Como: chestnuts, oaks, beechs altitude 400 m
Station n.	2 Woods south of Como: chestnuts, oaks, pines altitude 200 m
Station n.	3 Piano del Tivano: beechs, alders, hornbeams hazels altitude 1000 m
Station n.	4 Mountains around Canzo chestnuts oaks, pines altitude 1000 m
Station n.	5 Alto lago: beechs, oaks, chestnuts altitude 300 m
Station n.	6 Alta Valsassina: chestnuts, pines, firs altitude 1000 m
Station n.	7 Valle Imagna: oaks, chestnuts, hornbeams altitude 800 m
Station n.	8 Valle Intelvi: oaks, chestnuts, pines altitude 800 m
Station n.	9 Bassa Valtellina: oaks, chestnuts altitude 400 m
Station n.	10 Besana Brianza: oaks, pines altitude 200 m
Station n.	11 Brughiera Saronno, Busto Arsizio: pines, oaks, chestnuts altitude 150 m
Station n.	12 around Lago Maggiore and Lago di Varese: pines, chestnuts, oaks altitude 150 m
Station n.	13 Piné near Trento: pines and red firs altitude 900-1800 m

Table III — Cs-137 fall-out in open grassy soils, Becquerel/m²

Como	34300	Melide	59000
M. Bisbino	85100	Porlezza	40400
Bellagio e Perlo	69600	Chiavenna	49100
Piano Tivano	36100	Ardenno	32400
Lasnigo	24600	Pedesina	37700
Cantù	13500	Tirano	11130
Olginate	14500	Bolzano	9000
Bergamo	55600	Tarvisio	33000
Ispra	16600	Raccolana	41200
Angera	12800	Resia	38650
Malpensa	22500		
Luino	28200		

The intensity of fall-out has been measured in many stations both in Lombardy and in other Northitalian regions.

The fall-out, given in Becquerel/square metre is generally referred to grassy plain open soils; we report in Table III the Cs-137 data for the alpine stations related to the present analysis and refer for a more extended analysis to Facchini et al. 1987.

The fall-out data are indicative of the Cesium level in the areas in proximity of the sampling stations.

The data are however not exactly related to the stations; an incertitude of 30% can be estimated.

We report in the Table also the fall-out in a few sites in Friuli and in Bolzano, data which will be utilized in the following.

Results and discussion

The Cs-134 and Cs-137 concentrations are reported in Tables IV-VII; for a number of samples the K-40 concentration is reported.

The data are referred to each station and to a given macromicetes species; Tables A refer to the 1986 sampling, Tables B to 1987 and Table C to 1988.

From the general examination of the results, we notice that for K-40 there is a certain uniformity among the quantities absorbed by the various species (independently on their life-cycle and on the environment); on the contrary we notice a remarkable variability in the absorption of Cs-137, with the consequence of a remarkable variation of the ratio Cs-137/K-40.

This ratio in the most part of the mushrooms is lower than 1, but in the species where we have found the highest contents in Cs-137 the ratio becomes quite greater.

It is interesting to notice that mushrooms collected in the same area, which belong to different species, show different contents of Cs-137. A typical example concerns *Amanita muscaria* and *Amanita phalloides*, picked up in the same pine-wood near Montagnaga di Piné, where the samples of the two species were intermingled.

Table IV — Samples from Circolo Micologico Plinio il Vecchio

A) Autumn 1986

	K-40	Cs-137	Cs-134	Cs-137/K-40
Station n. 1				
<i>Armillariella mellea</i>	166	45	20	0.27
<i>Cantharellus cibarius</i>	217	192	67	0.88
<i>Cortinarius praestans</i>	98	28.5	7.4	0.29
<i>Fistulina hepatica</i>	144	28	6.3	0.19
<i>Gyroporus castaneus</i>	163	14	6	0.08
<i>Leccinum aurantiacum</i>	172	35	13	0.20
<i>Lepiota procera</i>	171	58	25	0.34
<i>Lycoperdon maximum</i>	164	7.4	3.3	0.04
<i>Polyporus umbellatus</i>	92	6.7	0.17	
<i>Polyporus pes caprae</i>	81	27	13	0.33
<i>Tylopilus felleus</i>	81	661	177	8.16
<i>Xerocomus badius</i>	217	2586	1073	11.90
Station n. 2				
<i>Amanita muscaria</i>	*	155	41	-
<i>Clitocybe nebularis</i>	126	126	58	1.0
<i>Coprinus comatus</i>	78	6.3	2.6	0.08
<i>Lactarius circellatus</i>	99	21	11	0.24
<i>Lactarius quietus</i>	126	1698	729	13.40
<i>Lactarius quietus</i>	218	4181	1624	19.20
<i>Lepiota puellaris</i>	102	7.4	2.6	0.07
<i>Lepista nuda</i>	104	54	27	0.52
<i>Lepista glaucocana</i>	226	1761	752	7.79
<i>Paxillus involutus</i>	118	83	55	0.70
<i>Russula sardonia</i>	137	1058	444	7.72
<i>Russula nigricans</i>	55	155	59	2.81
<i>Tricholoma portentosum</i>	166	55	32	0.33
<i>Xerocomus badius</i>	97	2926	1225	30.16
Station n. 3				
<i>Boletus edulis</i>	111	166	63	1.49
<i>Bovista plumbea</i>	62	91	40	1.46
<i>Lycoperdon saccatum + perlatum</i>	57	66	28	1.15
Station n. 4				
<i>Amanita muscaria</i>	37	137	55	3.70
<i>Amanita muscaria</i>	123	257	86	2.08
<i>Hebeloma sinapizans</i>	76	1003	287	13.19
<i>Lactarius quietus</i>	87	3430	1469	39.42
<i>Suillus granulatus</i>	41	175	68	4.26
Station n. 5				
<i>Boletus erythropus</i>	98	216	46	2.20
Station n. 7				
<i>Lepista glaucocana</i>	92	1498	625	16.28
Station n. 9				
<i>Boletus edulis</i>	80	37	5.2	0.46
<i>Clavaria botrytis</i>	129	22	6	0.17
<i>Hydnum imbricatum</i>	155	214	21	1.38
<i>Leccinum aurantiacum</i>	157	147	55	0.93
<i>Polyporus ovinus</i>	133	15.2	6.3	0.11

Table IVB

B) Autumn 1987	K-40	Cs-137	Cs-134	Cs-137/K-40
Station n. 2				
<i>Amanita muscaria</i>	147	70	16.6	0.47
<i>Amanita citrina</i>	136	757	209	5.56
<i>Clitocybe nebularis</i>	105	159	48	1.51
<i>Clitocybe clavipes</i>	37	1850	592	50.00
<i>Cortinarius praestans</i>	116	68	15	0.58
<i>Hypholoma sublateritium</i>	101	195	40	1.93
<i>Lactarius quietus</i>	292	7666	2290	26.25
<i>Lactarius quietus</i>	121	2229	641	18.42
<i>Lactarius chrysorreus</i>	163	2272	626	13.93
<i>Lactarius turpis</i>	71	104	30	1.46
<i>Lepiota naucina</i>	102	31	10	0.30
<i>Lepista nuda</i>	101	13	5	0.13
<i>Lycoperdon perlatum</i>	63	59	16	0.93
<i>Paxillus involutus</i>	67	481	144	7.18
<i>Suillus bovinus</i>	114	620	187	5.43
<i>Tricholoma saponaceum</i>	191	107	15	0.56
<i>Tricholoma portentosum</i>	160	190	37	1.18
<i>Xerocomus badius</i>	146	10309	3236	70.60
<i>Xerocomus badius</i>	109	3353	997	30.76
<i>Xerocomus badius</i>	92	1258	381	13.67
<i>Xerocomus rubellis</i>	171	132	37	0.77

Station n. 5

<i>Xerocomus badius</i>	85	1184	385	13.92
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Station n. 9

<i>Clavaria botrytis</i>	161	32	6	0.20
<i>Boletus edulis</i>	128	240	54	1.87
<i>Lepiota procera</i>	249	476	160	1.91

Table IV C

C) Autumn 1988	K-40	Cs-137	Cs-134	Cs-137/K-40
Station n. 1				
<i>Xerocomus badius</i>	192	1984	406	10.3
<i>Xerocomus badius</i>	163	1694	358	10.3
Station n. 2				
<i>Amanita muscaria</i>	64	390	77	6.0
<i>Armillariella mellea</i>	78	22	4	0.28
<i>Clitocybe nebularis</i>	60	63	15	1.05
<i>Hypholoma sublateritium</i>	47	42	8	0.89
<i>Lactarius chrysorreus</i>	105	3024	641	28.8
<i>Russula sardonia</i>	93	930	195	10.0
<i>Tricholoma portentosum</i>	189	148	18	0.78
<i>Xerocomus badius</i>	92	3515	758	38.2
Station n. 5				
<i>Tricholoma colossus</i>	66	88	12	1.33
<i>Xerocomus badius</i>	83	467	93	5.62
Station n. 9				
<i>Clitocybe clavipes</i>	89	2568	537	28.8
<i>Pholiota caperata</i>	130	403	22	3.1
<i>Xerocomus badius</i>	132	1753	316	13.2

Table V — Samples from U.S.S.L.

A) Autumn 1986

	K-40	Cs-137	Cs-134	Cs-137/K-40
Station n. 2				
<i>Boletus edulis</i>	*	286	113	-
<i>Lepiota procera</i>	*	18	14	-
<i>Lycoperdon saccatum</i>	*	46	21	-
<i>Lycoperdon maximum</i>	*	7	-	-
<i>Suillus bovinus</i>	*	1953	889	-
<i>Xerocomus ferrugineus</i>	*	97	28	-
Station n. 4				
<i>Armillariella mellea</i>	*	186	68	-
<i>Armillariella mellea</i>	*	30	13	-
<i>Boletus edulis</i>	*	338	133	-
<i>Boletus edulis</i>	*	181	49	-
<i>Lycoperdon saccatum</i>	*	66	-	-
Station n. 6				
<i>Boletus edulis</i>	*	129	54	-
<i>Boletus edulis</i>	*	49	18	-
<i>Boletus edulis</i>	*	31	14	-
Station n. 8				
<i>Lepiota procera</i>	*	63	30	-
<i>Lycoperdon maximum</i>	*	255	125	-
Station n. 9				
<i>Armillariella mellea</i>	*	145	66	-
Station n. 11				
<i>Armillariella mellea</i>	*	79	40	-
<i>Boletus edulis</i>	*	131	54	-
<i>Clitocybe nebularis</i>	*	36	15	-
<i>Hydnum repandum</i>	*	1159	455	-
<i>Leccinum aurantiacum</i>	113	33	13	0.29
<i>Lepiota procera</i>	*	93	44	-
<i>Lepiota procera</i>	109	15	6	0.14
Station n. 12				
<i>Clitocybe nebularis</i>	120	38	16	0.31
<i>Clitocybe nebularis</i>	179	15	5	0.08
<i>Cortinarius praestans</i>	90	37	18	0.41
<i>Hydnum repandum</i>	142	1563	231	11.00
<i>Lepista nuda</i>	120	1082	425	9.01
<i>Xerocomus badius</i>	162	1566	574	9.66
<i>Xerocomus badius</i>	*	1074	477	-

Table V - Samples from U.S.S.L.

B) Autumn 1987

	K-40	Cs-137	Cs-134	Cs-137/K-40
Station n. 2				
<i>Clitocybe nebularis</i>	*	96	24	-
<i>Clitocybe nebularis</i>	*	133	-	-

Table V — Samples from U.S.S.L.

	K-40	Cs-137	Cs-134	Cs-137/K-40
<i>Fistulina hepatica</i>	< 113	182	35	> 1.60
<i>Lactarius vellereus</i>	< 66	883	128	> 13.30
<i>Leccinum scabrum</i>	< 89	1827	546	> 20.50
<i>Lepiota procera</i>	*	64	-	-
<i>Lepista nuda</i>	160	50	13	0.31
<i>Lycoperdon saccatum</i>	291	682	< 41	2.34
<i>Paxillus involutus</i>	181	407	133	2.24
<i>Paxillus involutus</i>	73	26	8	0.35
<i>Xerocomus badius</i>	324	2704	811	8.34

Station n. 10

<i>Auricularia Auricula</i>	181	208	84	1.15
-Judae				
<i>Pholiota mutabilis</i>	122	138	56	1.13
<i>Polyporus squamosus</i>	69	15	5	0.22
<i>Stropharia ferrii</i>	253	369	145	1.46
<i>Tricholoma georgii</i>	80	807	< 24	10.00

Table VI — Samples from C.C.R. (Ispra)

A) Autumn 1986

	Cs-137 aver.	Cs-134 aver.
Station n. 12		
<i>Amanita muscaria</i>	48.1	22.2
<i>Amanita vaginata</i>	22.2	7.4
<i>Armillariella mellea</i>	88.8	37.0
<i>Boletus aereus</i>	8.1	6.3
<i>Boletus edulis</i>	107.8	34.3
<i>Boletus erythropus</i>	118.4	55.5
<i>Boletus impolitus</i>	10.0	4.4
<i>Boletus luridus</i>	92.5	37.0
<i>Boletus purpureus</i>	62.9	14.8
<i>Cantharellus cibarius</i>	888.0	292.3
<i>Cantharellus lutescens</i>	625.3	262.7
<i>Clitocybe clavipes</i>	5698.0	2664.0
<i>Clitocybe nebularis</i>	103.6	37.0
<i>Collybia velutipes</i>	25.9	3.7
<i>Gyroporus cyanescens</i>	13.0	4.1
<i>Hydnum repandum</i>	1480.0	580.9
<i>Ixocomus elegans</i>	427.4	142.5
<i>Ixocomus luteus</i>	111.0	48.1
<i>Leccinum aurantiacum</i>	170.2	66.6
<i>Leccinum scabrum</i>	1058.2	414.4
<i>Lepiota procera</i>	59.2	25.9
<i>Lepiota naucina</i>	447.7	185.0
<i>Lycoperdon perlatum</i>	129.5	51.8
<i>Lycoperdon maximum</i>	5.2	3.7
<i>Marasmius oreades</i>	155.4	70.3
<i>Pleurotus ostreatus</i>	25.9	7.4
<i>Psalliota campestris</i>	282.7	127.7
<i>Russula cyanoxantha</i>	151.7	40.7
<i>Russula virescens</i>	62.9	18.5
<i>Tricholoma columbetta</i>	151.7	55.5
<i>Tricholoma portentosum</i>	126.9	32.9
<i>Tricholoma saponaceum</i>	237.5	93.2
<i>Xerocomus badius</i>	1658.7	682.1
<i>Xerocomus chrysenteron</i>	7.3	3.7
<i>Xerocomus subtomentosus</i>	1653.9	666.0

Table VI — Samples from C.C.R. (Ispra)

B) Autumn 1987

Station n. 12	Cs-137 aver.	Cs-134 aver.
Armillariella mellea	21.2	6.2
Boletus edulis	371.5	95.0
Clitocybe clavipes	7512.0	2480.0
Hydnum repandum	423.5	124.9
Leccinum scabrum	47.0	13.0
Sparassis crispa	139.5	40.6
Suillus bovinus	2317.6	731.9
Tricholoma portentosum	69.0	21.4
Xerocomus badius (n. 9 samples)	2540.3	768.0

Table VII - Samples from Piné di Trento

A) Autumn 1986

	K-40	Cs-137	Cs-134	Cs-137/K-40
<u>Montagnaga</u>				
Amanita muscaria	63	24	3.7	0.38
Amanita phalloides	79	178	60	2.25
Suillus bovinus	43	94	28	2.18
Lactarius vellereus	82	8	4	0.10
Russula sanguinea	72	32	8.5	0.44
<u>Stramaiole</u>				
Amanita muscaria	31	10	3.7	0.33
Polyporus ovinus	89	35	5	0.40

B) Autumn 1987

<u>Montagnaga</u>				
Amanita muscaria	128	34	5	0.26
Amanita phalloides	170	689	181	4.5
Cantharellus tubiformis	-	318	82	-
Cantharellus lutescens	118	696	197	5.90
Clitocybe candida	76	5	-	0.07
Craterellus cornucopioides	204	37	6	0.18
Lycoperdon perlatum	82	-	-	0.00
<u>Stramaiole</u>				
Amanita muscaria	86	24	3	0.28
Russula mustelina	146	32	3	0.22

The Cesium level should depend first of all on the content of this radioisotope in the soil but also on the specific characteristic of the mushrooms species.

It appears interesting, to investigate the relation between the Cs-137 content and the biologic characteristic of the various species. We find relevant Cesium levels in micorrizic species as *Xerocomus badius* but very low levels in other micorrizic ones as *Gyroporus castaneus* and *Tricholoma portentosum*.

Similar large variations in Cesium levels are found in saprophitae: large levels in *Lepista glaucocana*, in *Clitocybe clavipes* and very low levels in other saprophitae as *Lepista nuda*.

The depth of the mycelium in soil and the Cesium penetration in underground should play an important role.

On the other side we observe low Cesium levels in parasitic species, as *Fistulina hepatica*, *Armillariella mellea*: it appears that the quantity of radioisotopes absorbed by higher plants is not remarkable for the parasitic mushrooms.

For a given species it is interesting to test a possible relation between the Cesium level in macromicetae and the fall-out level in the area itself. The comparison can be done, with accuracy, only in a few cases: we have at our disposal the data for a given species in a few sites only; moreover the fall-out data are quite uncertain: A similar analysis has been made by Nimis (Nimis et al. 1986) for the Friuli mushrooms; these authors show a rough relation where higher is the estimated fall-out level, higher is the Cesium content in mushrooms.

A linear relation between fall-out and cesium in mushrooms can be established by considering together our results, those of Nimis and data given by Bellù and Moroder (Bellù, Moroder 1986).

The comparison is given for three species: *Amanita muscaria*, *Hebeloma Sinapizans*, *Xerocomus subtomentosus*. As shown in Table VIII the mushrooms picked up in the areas where Cesium presence is very high, higher than in other areas, show us higher levels than the mushrooms picked up in the grounds where the presence of Cesium is more limited.

In the Friuli upper valleys we had strong rains on april 29th when the radioactive cloud was arriving from east and we had similarly strong rains in the Como' Lake territory in the first days of may 1986; in other sites as Bolzano we had a low fall-out level, related to the dry deposition.

The results of Table VIII are presented in Fig. 2: linear dependence between the total fall-out and the Cesium concentration in mushrooms is observed; quite interesting is the fact that the intercept of the straight lines are not at zero fall-out, but correspond roughly at the dry fall-out value around 8000 Bq/m².

Other species show this linear dependence, such as *Amanita phalloides*.

In other cases, as for *Armillariella mellea*, the Cesium levels seem to be independent on the Cesium content in soil; we recall however that these mushrooms are parasitic.

Another interesting comparison can be done between the 1986 levels and the 1987 and 1988 ones. The comparison is made for mushrooms of the same species and collected in the same site. Selecting the data from tables IV-VII we have formed

Table VIII — Cs-137 concentration in macromicetae and in soil

	Bq/kg	Bq/m ²
<i>Amanita muscaria</i>		
- Bolzano	5	8700
- Friuli sito 4 (passo del Pura)		
sito 18 (Val d'Ayer)	37	13000-13600
- Piné (2 valori)	17	15400
- Ispra	48	18600
- Groane comasche	135	23300
- Friuli sito 27 (Fusine)	54	28600
- Monti Lariani est.	197	68000
<i>Hebeloma sinapizans</i>		
- Siti Friuli 8 (Castelmonte)		
e 9 (M. Matajur)	90	10100
- Sito Friuli 3 (Ampezzo)	389	13000
- Monti lariani est.	1002	68000
<i>Xerocomus subtomentosus</i>		
- Bolzano	17	8700
- Friuli 8 (Castelmonte)		
e 10 (M. Matajur)	235	10100
- Ispra	1654	18600
- Friuli 33 (Uccea)	1125	19000

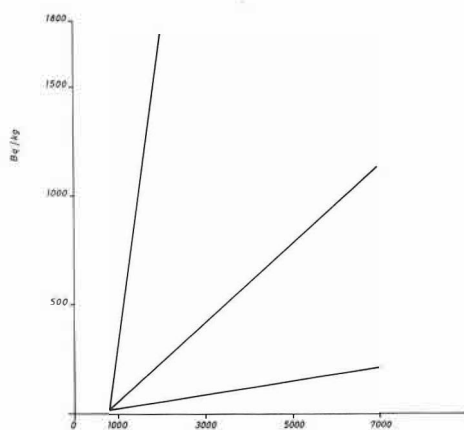


Fig. 2 — Relations between Cs-137 in soils (abscisse) and in 3 mishroom species (*Amanita muscaria*, *Hebeloma sinapizans* and *Xerocomus subtomentosus*, see text).

Table IX, where we generally observe a stationary Cesium level in 1987, but also a possible decrease of Cesium levels in 1988 samples. It is necessary to recall that in woodland Cesium persists for long times. Moreover, the deeper penetration of Cesium in soil can possibly offer a more rich Cesium content to the mushrooms hyphae.

Table IX — Cs-137 levels in macromycetae: comparison autumn 1986 - autumn 1987 - autumn 1988

	1986	1987	1988
Station n. 1-2			
<i>Amanita muscaria</i>	155	70	390
<i>Armillariella mellea</i>	45	--	22
<i>Clitocybe nebularis</i>	126	96-159	63
<i>Cortinarius praestans</i>	28	68	--
<i>Fistulina hepatica</i>	28	182	--
<i>Hypholoma sublateritium</i>	--	195	42
<i>Lactarius crysorreuus</i>	--	2272	3024
<i>Lactarius quietus</i>	1698-4181	2229-7666	--
<i>Lepiota procera</i>	18-58	64	--
<i>Lepista nuda</i>	54	13-50	--
<i>Lycoperdon saccatum</i>	46	682	--
<i>Paxillus involutus</i>	83	26-481	--
<i>Russula sardonia</i>	1058	--	930
<i>Tricholoma portentosum</i>	55	190	148
<i>Xerocomus badius</i>	2586-2926	1258-10309	1694-3515
Station n. 5			
<i>Xerocomus badius</i>	--	1184	467
Station n. 9			
<i>Boletus edulis</i>	37	240	--
<i>Clavaria botrytis</i>	22	32	--

As a last point we investigate the ratio between the Cesium isotopes, Cs-134/Cs-137. The ratio between the Cs isotopes in fall-out and in soil when referred to may 1986 was c.a. 0.45.

The decay of Cs-134 shall reduce this ratio in a predictable way when considering the autumn of 1986 and then the autumn of 1987 and 1988.

When considering that the measurements are referred to december we have the following values of the ratio (R):

ratio Cs-134 / Cs-137 december 1986 R = 0.37
 december 1987 R = 0.26
 december 1988 R = 0.19

We can observe that in most mushrooms samples the ratio of the two Cesium isotopes reflects the fall-out composition.

Let us consider for instance the data for: Cs-134/Cs-137 average ratio (R):

<i>Xerocomus badius</i>	1986: 0.40	(5 samples)
	1987: 0.30	(6 samples)
	1988: 0.20	(5 samples)
<i>Amanita muscaria</i>	1986: 0.36	(4 samples)
	1987: 0.23	(1 sample)
	1988: 0.19	(1 sample)
<i>Clitocybe nebularis</i>	1986: 0.39	(5 samples)

	1987: 0.27	(3 samples)
	1988: 0.24	(1 sample)
<i>Lactarius quietus</i>	1986: 0.41	(3 samples)
	1987: 0.29	(2 samples)

The predicted value is generally verified where the Cs-137 level is sufficiently high; in miscellaneous samples, 34 samples with Cs-137 concentration greater than 100 Bq/Kg, the average ratio is:

$$1986 \text{ average } R = 0.375$$

In samples and in species where the Cs-137 level is quite low, statistical errors and incertitudes do not give a precise value of the ratio R.

In *Armillariella mellea* a species with low Cs-137 level, many measurements are available; we obtain for 1986:

Lombardy values (6 samples)	R = 0.43
Friuli values, (from Nimis, 21 samples)	R = 0.37
average	R = 0.40
For 1987 (1 sample)	R = 0.29
For 1988 (1 sample)	R = 0.18

On the contrary in a number of species, and particularly when Cs-137 level is low, there are anomalous values of the ratio R and an excess of Cs-137 over Cs-134.

Let us consider *Boletus edulis* in 1986:

3 samples with Cs-137 < 100 Bq/Kg	R = 0.31
7 samples with Cs-137 100 - 338 Bq/Kg	R = 0.36

The ratio R decreases when the Cs-137 concentration is lower; this behaviour can be observed, for a number of species, even from Nimis' results and particularly for: *Hebeloma sinapizans*, *Hebeloma birrum*, *Hygrophorus eburneus*, *Tricholoma vaccinum*.

A confusing element can be the presence in soil and then in mushrooms of residual Cs-137 related to the fall-out of the decade 1955-65, due to the experimental nuclear explosions in atmosphere. This Cesium is still in woodland; the old Cs-137 is present in the underground, at a depth of a few centimeters.

It is possible that given mushrooms species absorb in sensible quantity the Cesium at this depth. For proving this point, we have examined samples of mushrooms picked up in the year 1985, before Chernobyl, and in the year 1986, after Chernobyl, in the same site. The comparison was performed on samples of *Boletus edulis* collected in Ora di Trento; the data obtained, for dried samples are the following:

- samples of 1985	K-40	677	Cs-134	—	Cs-137	27
- samples of 1986	K-40	585	Cs-134	26	Cs-137	214

Table X — Ratio Ag-110 (m) / Cs-137 in macromicetae samples

Lactarius quietus	0.003 - 0.004
Xerocomus badius	0.003
Russula sardonia	0.006
Lepista glaucocana	0.01
Amanita muscaria	0.01 - 0.03
Lepista nuda	0.07
Paxillus involutus	0.11
Clitocybe nebularis	0.09 - 5.6
Lepiota procera	0.22 - 1.8
Bovista plumbea	0.24
Lycoperdon perlatum	0.27
Lycoperdon maximum	0.7 - 1.1
Lycoperdon saccatum	3.5

The data are given in Becquerel/dried Kg.

It appears that a given quantity of Cesium 137 was still present in the 1985 samples.

In these species the old Cesium 137 influences the isotopic composition and the ratio R is reduced. But when the recent Cesium 137 reaches higher levels, the old Cesium plays a minor role and the ratio Cs-134/Cs-137 approaches the expected values.

We conclude this discussion observing that in a few species, as *Hydnum* or *Sarcodon imbricatum* the ratio R remains constantly below the predicted values.

From Nimis results we have in 1986:

Cs-137	38-208	Bq/Kg	R = 0.10
Cs-137	291-376	"	R = 0.15
Cs-137	812	"	R = 0.11

the measurements given by us (Table IV A) give:

Cs-137	214	Bq/Kg	R = 0.10
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Let us finally discuss the level of Ag-110: in most species Ag-110 has not been observed, i.e. is the level of this isotope is below the sensitivity threshold of the Germanium spectrometer; however, in a few samples the Ag is present in large quantity and the ratio Ag-110/Cs-137 is quite higher in the mushrooms than in the ground fall-out.

In Table X we have collected these remarkable data.

Riassunto: lo studio è basato sulla misura del Cesio - 134 e del Cesio - 137 in campioni di macromiceti, appartenenti a specie diverse. I campioni sono raccolti in 13 siti della Lombardia, in territori attorno al Lago di Como e al Lago Maggiore e alcuni campioni in Piné di Trento. La raccolta di maggior impegno è fatta nell'autunno 1986, pochi mesi dopo l'incidente di Chernobyl; raccolte successive sono datate nell'autunno 1987 e 1988. Le raccolte sono state fatte: dal Circolo Micologico Plinio il Vecchio, di Como: dalle Unità Sanitarie di Como e Varese e dal Servizio Radioprotezione del Centro Comune di Ricerca di Ispra.

Significative differenze nei livelli di Cesio sono osservate per campioni di differenti specie e anche nelle differenti stazioni di raccolta.

I valori vengono interpretati con difficoltà in ragione delle tipologie dei macromiceti e con riferimento al livello di radioisotopi nel terreno, questi legati alle intensità delle piogge nei giorni del passaggio della nube di Chernobyl. In alcuni campioni è stato rilevato anche l'Ag-110 e in molti di essi è stata misurata la concentrazione di K-40, un elemento questo presente in natura.

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ASSESSMENT OF METAL AIR POLLUTION BY EPIPHYTIC LICHENS: THE INCIDENCE OF CRUSTAL MATERIALS AND OF THE POSSIBLE UPTAKE FROM SUBSTRATE BARKS.

Roberto BARGAGLI

Keywords: Biomonitoring, Lichens, Heavy Metals, Pollution.

Abstract: The amounts of Al, Cu, Fe, Mn, and Zn in the epiphytic lichen *Parmelia sulcata* Tayl. and in surface soils of Mt. Amiata (central Italy) were measured. Using Al as a reference element, the data were normalized and background concentrations were established.

In a separate trial, concentrations of the above elements in outer and inner barks of supporting trees (oak, chestnut, and beech) were determined. The possibility of an uptake of some elements from the substrate, although not very likely, cannot be excluded completely.

Introduction

There is a great number of publications dealing with the use of lichens as biomonitors of air pollution in central and northern Europe; in the Mediterranean region these studies are very scanty even though it has been shown that some species of foliose epiphytic lichens growing in central Italy are suitable monitors of metal air pollution around industrial plants as well as in a mercury mining area (Bargagli *et al.*, 1985; Bargagli *et al.*, 1987 a).

However, in interpreting metal deposition patterns by lichens, considerable attention should be paid to certain physiological and temporal aspects of the metal uptake. There is still much to be learned about the uptake of metal ions (Richardson *et al.*, 1985) and about the capacity of the different species of lichens to retain and to accumulate metals. Moreover it has been shown that even in epiphytic species (Olmez *et al.*, 1985), soil and rock dust particles trapped in the medulla contribute significantly to the total concentrations of several elements.

The possibility of some metal uptake by epiphytic lichens directly from the bark through the rhizines or indirectly from the water flowing along the trunk (de Bruin, 1985) is another possible interference which should be taken into account when using metal concentrations in lichens as an index of metal air pollution.

In order to ascertain the reliability of epiphytic lichens as a tool in the evaluation

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of air pollution in central Italy, this study was undertaken with the following objectives:

- a) to assess the background concentrations of Fe, Mn, Cu, Zn and Al in one of the most widespread species: *Parmelia sulcata* Tayl.;
- b) to point out possible relationships between the concentrations of elements in the lichen and those in the soil;
- c) to evaluate the possibility of metal uptake from different bark types.

Materials and methods

Thalli of *P. sulcata* Tayl. were collected in spring and autumn 1986 from 50 sites on Mt. Amiata on the bark of oak, chestnut and beech (the tree species varied according to altitude and to soil type). Mt. Amiata is an isolated mountain in southern Tuscany which arose from Pleistocene volcanic eruptions; trachytic materials (from about 800 m to the top of the mountain) (Fig. 1) lie on sedimentary formations. While soils deriving from sedimentary rocks are basic or neutral with a low permeability and the associated vegetation is constituted by the pubescent oak series (Arrigoni e Nardi, 1975), volcanic soils are acid and highly permeable and sustain two plant communities: chestnut woods from about 800 to 1100 m and beech-woods all over the mountain. In this area there are no sources which would

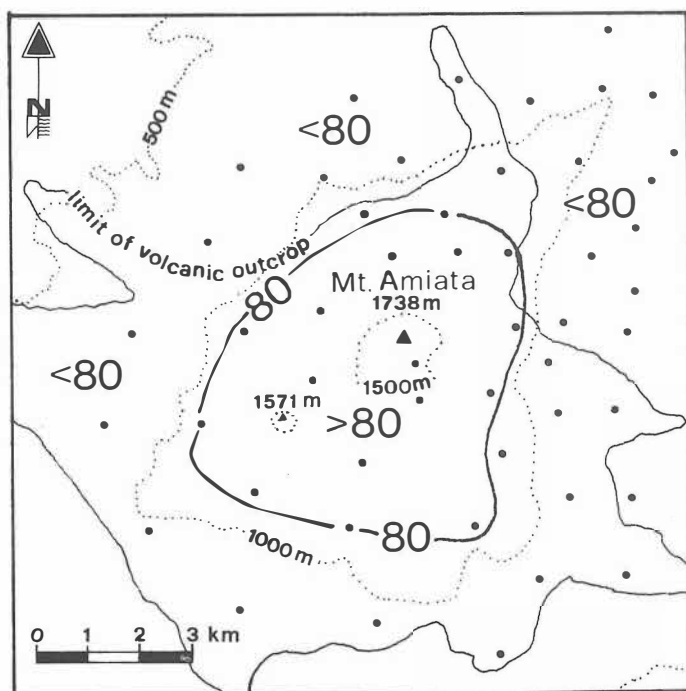


Fig. 1 — The study area, sampling sites and Zn concentrations (μg^{-1})

lead to an anomalous uptake of the metals under study. At each site 3 samples of surface soil (0-5 cm) and 4 or 5 whole thalli of *P. sulcata* were collected at a height of 1.5-2 m above the ground and combined. In 18 stations (6 for each tree species) in addition to lichen thalli, the attached barks were also collected.

In the laboratory soil samples were air-dried, sorted to remove gravel and the larger particles of organic debris, then sieved at 250 μm . The outermost part of lichen thalli (4-5 mm) (which is easily recognizable since it has a different colour) was excised for analytical determinations. In fact, the older parts of the thallus contain significantly higher metal concentrations (Bargagli *et al.*, 1987 b) and to obtain relatively comparable values, it is advisable to analyse portions of the thallus of the same age. Since in foliose lichens it is impossible to ascertain the age of the different zones, the better solution seems to be the analysis of the easily recognized outermost zone of the thallus, which presumably constitutes the biomass developed over the previous year, is the most physiologically active portion, and has scanty connections with the bark.

Barks were separated into two parts: the outer layer (2-3mm) and the inner layer (light-brown).

About 150 mg of dried and homogenized samples were mineralized with conc. HNO_3 at 120° C for 8 h in a pressure decomposition system. Concentrations of trace elements were determined by A.A.S. using the graphite furnace for Al and the air/acetylene flame for the other elements. Metal concentrations were calculated on a dry weight basis and the results of the two batches (spring and autumn) were averaged, since they did not differ in all elements by more 15% (i.e. a value roughly corresponding to the coefficient of variation calculated from replicate analyses of three samples).

To check the analytical method, the NBS Standard Reference Material n° 1572 "Citrus leaves" was analyzed. Mean percent recovery and standard deviation ($n = 20$) was: Fe = $94 \pm 8\%$; Mn = $96 \pm 9\%$, Cu = $93 \pm 3\%$, Al = $103 \pm 14\%$.

Results and discussion

Table 1 presents the averages and ranges of metal concentrations in superficial soils and in the lichen thallus. Although comparisons with literature data are made difficult by the different characteristics of samples and by the different analytical procedures, the averages and ranges of element contents reported in Tab. 1 roughly correspond to those reported for other background areas (Kabata-Pendias and Pendias, 1985; Olmez *et al.*, 1985; Romero *et al.*, 1987; Bargagli *et al.*, 1987b).

Clayey soils deriving from sedimentary rocks have a significantly higher content of metals than volcanic soils (from the t-test, $P < 0.01$). However, except in the case of Mn, this distribution is not reflected in lichens. Rather, as shown in Fig. 1, the highest concentrations of Zn, occur in samples collected on beech trunks, in the upper part of the mountain.

In a previous study (Bargagli *et al.*, 1987a) the concentrations of Hg in *P. sulcata* were very significantly related to those in superficial soil (probably as a consequen-

Tab.1— Summary values ($\mu\text{g.g}^{-1}$ d.w.) for the 5 elements in surface soil (0-5 cm) and in the outermost zone of *P. sulcata* thalli ($n = 50$).

	SOIL		LICHEN	
	range	avg \pm SD	range	avg \pm SD
Al	10,700 - 49,000	24,800 \pm 12,000	240 - 2,980	1,403 \pm 714
Cu	7.0 - 88.0	42.6 \pm 14.6	3.4 - 12.5	9.6 \pm 2.2
Fe	8,400 - 32,000	18,200 \pm 6,700	219 - 1,270	841 \pm 224
Mn	220 - 2,100	690 \pm 446	25 - 128	64 \pm 39
Zn	21 - 104	64 \pm 23	28 - 140	65 \pm 17

ce of the metal degassing from the cinnabar mineralized soil of Mt. Amiata); among the elements considered in the present study, only the Mn content in lichens seems somewhat related to that in soil ($r = 0.29$, $P < 0.05$). This result, together with the rather low concentrations of Al and Fe, seems to exclude a substantial contamination of samples by soil and rock dust suspended by wind. However, in the relatively pollutant-free area of Mt. Amiata, the elemental composition of lichen would reflect the crustal composition. Among lichen element, Fe concentrations correlate significantly ($r = 0.48$, $P < 0.001$) with those of Al, i.e. an element of limited metabolic significance in lichen (Puckett, 1985) and traditionally used as an indicator of crustal-derived materials. The low coefficients of correlation between almost all pairs of other element could suggest that they have not a common source. However, absolute values of element concentrations are difficult to interpret and could provide misleading assessment of their environmental distribution. By calculating an enrichment factor (EF):

$$EF = \frac{X \text{ lichen} / Al \text{ lichen}}{X \text{ soil} / Al \text{ soil}}$$

where X is the concentration of the element of concern, data are normalized and the fluctuations of absolute values which obscure the possible relationships among various elements, are removed.

From the calculations it turns out that only Zn has an high EF (mean = 19.4 ± 8.9), while those of Mn and Cu are < 5 and that of Fe is < 1 . Therefore, the low values of EFs suggest that Fe, Mn, and Cu derive their source essentially from crustal material. Instead, the high EF of Zn indicates a significant enrichment over the regional soils and average crustal values (Krauskopf, 1979). As shown in Fig. 1, the highest concentrations of Zn occur in samples collected on beeches and this may be due to the relation between the lichen thalli and the beech bark or to higher Zn input from the atmosphere in the upper part of Mt. Amiata.

In order to point out the possible relationships between the elemental composition of lichen and those of outer and inner barks, samples from each unit of vegetation were analyzed in a separate trial. Results are summarized in Tab. 2 and

Tab. 2 — Average elemental concentrations ($\mu\text{g}^{-1} \text{d.w.} \pm \text{SD}$) in surface soil, *P. sulcata*, outer and inner barks of the 3 natural units of the Mt. Amiata vegetation (6 samples per unit)

		SOIL	LICHEN	Outer BARK	Inner BARK
OAK	Al	29000 \pm 4800	1470 \pm 390	984 \pm 349	121 \pm 33
	Cu	71.4 \pm 12.6	9.8 \pm 3.7	10.3 \pm 3.3	9.6 \pm 2.6
	Fe	22500 \pm 4300	840 \pm 210	798 \pm 254	82 \pm 13
	Mn	914 \pm 220	99 \pm 49	273 \pm 118	314 \pm 231
	Zn	92 \pm 5	62 \pm 5	35 \pm 16	20 \pm 6
CHESTNUT	Al	18600 \pm 3950	1300 \pm 520	1070 \pm 254	280 \pm 186
	Cu	39.8 \pm 17.3	8.6 \pm 2.3	12.8 \pm 3.9	7.3 \pm 1.6
	Fe	14100 \pm 4250	680 \pm 220	1200 \pm 295	179 \pm 80
	Mn	371 \pm 154	81 \pm 40	522 \pm 410	132 \pm 70
	Zn	48 \pm 18	51 \pm 10	33 \pm 6	17 \pm 3
BEECH	Al	14200 \pm 3420	1710 \pm 540	742 \pm 309	242 \pm 128
	Cu	49.5 \pm 5.3	10.1 \pm 2.7	14.4 \pm 6.1	6.9 \pm 2.1
	Fe	17200 \pm 4380	820 \pm 295	715 \pm 180	233 \pm 147
	Mn	290 \pm 124	42 \pm 17	99 \pm 67	131 \pm 84
	Zn	58 \pm 7	87 \pm 4	30 \pm 7	40 \pm 11

are consistent with the lower content of metals in volcanic soil and the relationship between Mn concentrations in soil and those in *P. sulcata*. The higher content of Zn in lichens collected on beeches does not seem to be supported by as high concentrations of the metal in outer barks. Unexpectedly, the inner bark of beech has a significantly higher Zn content than the inner bark of chestnut and oak; and in theory, it cannot be excluded that a part of the Zn held in the lichen could derive from the supporting tree. De Bruin and Hackenitz (1986) also found concentrations of Ca, Mn, Zn, Cd, and Ba in the inner bark comparable or higher than those in the lichen and did not exclude this possibility. However, it must be borne in mind that in the present study, we analyzed only the outermost zone of the thalli, which lacks rhizinae and that there is no significant relationship between Zn concentrations in lichen and those in the inner bark.

The Mn content is much higher in the inner and outer bark of all trees than in lichen and in this case too, it seems unlikely that the element could reach the lichen through the supporting tree. In fact, concentrations in the inner barks, outer barks, lichen and soil are rather fluctuating and almost all are interrelated. Moreover, from data pertinent to all the study area, Mn concentrations in lichen are related only to those in surficial soil and, as previously found in *Parmelia caperata* (Bargagli *et al.*, 1987 c), in background areas, the Mn content in epiphytic lichen is generally lower than that in the supporting tree.

Lichens have a slight higher Al as well as Zn content with respect to that in outer barks, while their Fe and Cu concentrations roughly correspond to the bark levels. This is not surprising as lichen and tree barks are exposed to dry and wet depositions from the atmosphere and as a matter of fact, even tree barks are considered a sensitive and simple indicator of the air pollution (Grodzinska, 1979;

Nyangababo and Masami Ichikuni, 1986).

The outer bark of the chestnut, probably because of its greater roughness, has an higher Al and Fe content than the outer bark of oak and beech; while that of beech, which is the smoothest, has the lowest concentrations of the lithophile elements: Al, Fe and Mn.

Concentrations of Fe, Cu, and Al in the inner barks of all trees are steady and rather low, while those of Zn and Mn tend to correspond to those in outer bark in the oak, are significantly lower in the chestnut and slight higher in the beech.

Conclusions

The results presented, in agreement with previous data on other species of the genus *Parmelia* (Bargagli *et al.*, 1987 b) and on specimens of *Xanthoria parietina* (Bargagli *et al.*, 1985), permit us to establish that in unpolluted areas of central Italy, foliose, epiphytic lichens have a comparable content of trace elements in the outermost zone of their thallus (Al ranges from 300 to 1500 $\mu\text{g.g}^{-1}$; Cu from 4 to 12; Fe from 200 to 1000; Mn from 25 to 100 and Zn from 20 to 80). Values included in these ranges can be assumed as natural when metal concentrations in lichens are used as a measure of metal air pollution.

In the Mt. Amiata area, although the average content of Zn is within the background range, the high EF with respect to soil probably indicates a slight pollution of the air. This result is not surprising, as in another remote area (Wiersma *et al.*, 1987) it has been shown that this metal has long-range atmospheric transport characteristics and is partly of anthropogenic origin. This seems supported by the occurrence of the highest values in the upper part of the mountain, which is more exposed to moving air masses.

On the basis of the above reported results, an uptake of some elements from the supporting tree cannot be excluded completely. This does not seem very likely not even for Mn (i.e. the element with a much higher content in inner and outer barks than in lichen), since only the outermost zone of thalli has been analyzed and there are no significant relationships between metal concentrations in lichen and those in the inner bark. However, as suggested by de Bruin and Hackenitz (1986), this interference may be reduced by using lichen transplant.

In order to use lichens opportunely as a monitor of air pollution it is still more important to normalize raw concentrations of metals to the Al or Ti contents, as a large part of the suspended materials in air and a significant amount of elements in lichen and outer barks of trees arise from soil and rock dust suspended by wind.

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TERPENES OF SALVIA SPECIES LEAF OILS: CHEMOSYSTEMATIC IMPLICATIONS.

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Key Words. *Salvia* L. species, Labiatae, leaf oils, chemotaxonomy, pharmaceutical properties.

Abstract. Wild specimens of *Salvia* L. were collected in three different moments of anthesis and their volatile leaf oils were analyzed by GC/GCMS. The quantitative terpene composition is very variable with the anthesis. *S. bertolonii* is the richest species in α -thujone. *S. officinalis* is characterized by high percentages of 1,8 cineole, 4-terpineol, isorborneol and α -bisabolol. In *S. verticillata* high percentages of borneol and β -cariophyllene are present. In the three species α -thujone was always more abundant than β -thujone. The three taxa are characterized by peculiar combinations of terpenoids. The multivariate analysis of the chemical data indicates the degree of affinity between the three taxa and their chemotaxonomical status. Some components of *Salvia* essential oil have pharmaceutical activities.

Introduction

Salvia officinalis L., *S. bertolonii* Vis. and *S. verticillata* L. (Labiatae) are abundantly spread in the Karst Plateau, (N-E Italy, near Trieste).

S. officinalis is widespread in the *Salvieto-Euphorbietum fragiferae* (Lausi & Poldini 1962), s. restr. Poldini 1980 an association in which Labiatae and Euphorbiaceae prevail. It is a pioneer steppe-like association of the calcareous rocks along the litoral, in which the grassland communities are very discontinuous. (Lausi & Poldini 1962).

S. verticillata is present in ruderal vegetation and along the borders of the roads. *S. bertolonii* is a Balkan-endemic entity; it substitutes *S. pratensis* in the North-Eastern Adriatic region; its *Salvia* distribution is little known. (Poldini, 1978).

S. bertolonii is present in the association *Arrhenatheretum* Br.-Bl. ex Scherr. 25 (Karstic race). This association has a zoogenic origin; the consequences of centuries of pasture practised on deforested areas are a thin soil and a highly specialized vegetation: low, discontinuous and creeping. The climatic conditions are slightly more mesophytic than those of *Salvieto-Euphorbietum fragiferae*. These two Karstic *Salvia*-species had not been studied before from the point of view of their chemical composition.

S. officinalis from the isle of Pag (Dalmatia, Yugoslavia) was also examined, since it is the most commercially valued taxon.

The essential oil of this taxon as well as its productivity, the best stage of its sampling, the influence of the edaphic-environmental factors on the qualitative and quantitative composition of its essence were extensively studied (Devon, 1972; Steinegger & Hänsel, 1972; Dalferth, 1963; Banthorpe et al., 1977; Brieskorn & Kapadia, 1980; Holeman et al., 1983; Pitarevic et al., 1984; Kustrak et al., 1984; Bellomaria et al., 1988; Devetak et al., 1967; Tucakov, 1952; Cenci & Calvarano, 1967). As regards *S. officinalis* of the Karst Plateau, only the aminoacids and carbohydrates and some constituents of the essential oil (Poldini et al., 1971) were analyzed.

In the present study we report on the chemical differentiation of the three *Salvia* taxa and on the evidence of chemotaxonomic significance of the terpene composition. Several sources of biochemical data were used for systematic purposes, including the components of the essential oil (Emboden & Lewis, 1967; Kubeczka & Ullmann, 1983; Alston & Turner, 1963; Hegnauer, 1962; Vernet et al., 1977; Coassini Lokar et al., 1986; Corsi et al., 1984; Servettaz et al., 1984; Cenci & Calvarano, 1967).

In addition, the problem of various biological activities of some terpene derivatives, particularly α - and β -thujone, well known substances at high level of toxicity, was considered in relation to the commercial use of the drugs.

Materials and methods

Plant material and sampling

Several sets of leaf samples (from 15 individuals) were randomly collected in the North-Adriatic Karst territory in the mentioned associations, during the anthesis (pre-, full- and post- anthesis). All specimens are on deposit at TBS (accession number: 7290). Some samples of *S. officinalis* were collected from the *Stipo-Salvietum officinalis* H-ic (1956) 1958 in the isle of Pag (Dalmatia, Yugoslavia), during the pre-anthesis. This taxon was used as standard sample.

Distillation procedures

Fresh, weighed leaf material (125 g) was frozen until steam distilled. The volatile terpenoids were removed by steam distillation for 4 h for quantification analyses and for 24 h for yield calculations. Volatile oil yields were recorded as ml per 100 g of dry leaf weight. The extracts were kept at -20° until analyzed to minimize chemical degradation.

Methods of chemical analysis

GC/MS analysis were run with a Dupont 21492 B mass spectrometer coupled with a Varian 2700 gas chromatograph, using a glass column (3m x 2mm) packed with Carbowax 20M on Chromosorb W (80-100 mesh). All MS analysis were made

using the carrier with an average linear velocity through the column of 40 ml/min. The column temperature was programmed from 50° C (isot. 3 min) to 225° C at 10° min. The temperature of injector was 210° C and that of GC detector (FID) was 275° C. The EI mass spectra collected with a data system (HP 2109) were obtained at ionization voltage 75 e V, filament emission 250 μ A, source temperature 250° C. Quantification was made by peak area integration. The compounds were identified by comparison of their retention time and their mass spectra with those of authentic samples or/and MS of known terpenes and researcher of spectra from literature.

The GC-analysis of oils were carried out by Fractovap 2450 gaschromatograph (Carlo Erba) with a flame ionization detector and dual stainless steel column (2m x 2 mm), 10% Carbowax 20M on Chromosorb W (60-80 mesh); T° programmed from 60°C to 200°C at 4°C/ min; N₂ flow rate 30 ml/min; injector and detector temperature 250° C.

Methods of data analysis

Dissimilarities between the three taxa were computed with CHICORSOM method on the basis of chemical characters. The symmetric dissimilarity matrix was factored by principal components analysis (Eivava, Autovave, Copri 1, Copri 2) following the programs of Priscart and by the Euclidean distances following Dendro and Distance (Nie et al., 1970; Wishart, 1975; Feoli et al.; 1982a; 1982b).

Analysis of the results

The composition of the volatile leaf oils of the taxa (plus sample of Dalmatia) is shown in Table 1. The methods for the identification of components are indicated. The percentage data are average of three separated analysis. Of the 49 terpene derivatives, 32 were identified by GC/GCMS analysis and, when possible, by comparison with authentic samples of substances.

S. officinalis is characterized by high percentages of 1,8 cineole and α -bisabolol. The oxygenated terpenes and the hydrocarbons prevail. *S. verticillata* is characterized by the prevalence of β -cariophyllene and borneol; in *S. bertoloni* α - and β -thujone and β -cariophyllene prevail. In both these taxa the sesquiterpene hydrocarbons are prevalent. The percentages of chemical constituents show a wide range of variation during the anthesis. *S. verticillata* and *S. bertolonii* are more similar to *S. officinalis* (A' sample) as regards percentages of borneol and differ for β -cariophyllene. In the *S. officinalis* of the Karst Plateau (A sample) the percentage variation of some terpene constituents is more evident: during the anthesis only the yield of borneol tends to increase, while all the major constituents decrease. *S. officinalis* from Dalmatia (A' sample) differs from the Karst Plateau population for the percentages of 1,8-cineole, β -cariophyllene, borneol and δ -cadinene.

In *S. verticillata* α - and β -thujone, β -cariophyllene and isoborneol decrease with the anthesis; only borneol increases little. *S. bertolonii* is characterized by the absence of several low-boiling terpenes; at the stage of full anthesis it is

Table 1. — Percentage composition of the essential oils extracted from the leaves of *Salvia* species during the anthesis. (a = pre-anthesis, b = full-anthesis, c = post-anthesis; AS = authentic sample; A = *S. officinalis* from Karst Plateau; B = *S. officinalis* from Isle of Pag; C = *S. verticillata*).

N.	Compounds	Identification method	A'	S.officinalis (A)			S.bertolonii (B)		S.verticillata (C)		b	c
				a	b	c	a	b	c	a		
1	α-thujene	GC	AS	-	0.35	tr	-	0.27	-	-	0.37	-
2	α-pinene	MS-GC	AS	0.07	1.43	1.78	-	0.08	0.60	-	0.85	-
3	camphene	GC	AS	0.06	2.16	2.33	-	-	-	-	0.10	-
4	β-pinene	GC	AS	0.27	1.84	2.67	0.16	-	1.37	-	1.40	-
5	β-myrcene	MS-GC	-	0.06	0.34	0.23	0.08	-	-	-	0.35	-
6	α-phellandrene	MS-GC	-	6.00	0.05	tr	-	-	-	-	-	-
7	1,8-cineole	MS-GC	AS	4.78	15.93	19.10	0.44	0.38	-	0.34	1.60	0.80
8	limonene	MS-GC	AS	-	0.81	0.70	0.12	0.16	-	-	0.85	-
9	α-terpinene	MS	-	0.69	0.28	tr	0.20	0.21	-	-	1.10	-
10	p-cimene	MS-GC	AS	0.27	0.11	tr	-	-	-	-	-	-
11	γ-terpinene	MS-GC	-	-	tr	tr	-	-	-	-	-	-
12	ox.monot.MW 152	MS-GC	-	-	tr	tr	0.39	0.40	-	0.69	0.67	0.11
13	α-thujone	GC	AS	12.59	16.00	6.25	13.45	27.49	14.78	15.06	21.86	11.21
14	β-thujone	GC	AS	4.66	1.75	1.90	7.05	3.58	0.75	4.33	3.64	3.43
15	linalyl acetate	MS-GC	AS	0.41	tr	tr	-	-	-	-	-	0.59
16	camphor	MS-GC	AS	2.24	8.73	2.94	-	0.81	1.25	0.19	0.60	0.66
17	linalool	GC	AS	1.24	0.95	1.00	0.76	1.13	0.60	1.08	0.73	0.55
18	bornyl acetate	MS	-	0.78	1.03	0.97	11.00	-	-	-	-	-
19	*β-caryophyllene	MS-GC	AS	8.29	11.23	18.27	27.64	28.46	23.78	35.90	23.80	25.62
20	terpinen-4-ol	MS-GC	AS	0.43	0.07	tr	-	-	0.50	-	-	-
21	isoborneol	MS	-	6.51	8.57	10.26	4.76	2.64	1.20	5.04	4.10	3.53
22	borneol	MS-GC	AS	24.12	6.90	11.26	22.25	18.01	5.24	22.32	25.37	24.79
23	β-bisabolene	MS-GC	-	1.98	tr	tr	5.51	3.17	0.42	22.32	25.37	24.79
24	carvone	GC	AS	tr	0.05	tr	-	-	-	-	-	-
25	δ-cadinene	MS	-	4.28	1.77	0.10	3.52	1.98	1.12	2.72	2.80	2.94
26	myrtenol	MS	-	0.43	tr	tr	-	-	-	-	-	-
27	calacorene	MS	-	0.14	tr	tr	0.21	0.32	0.45	-	-	0.29
28	----	-	-	0.10	tr	tr	-	-	-	-	-	-
29	----	-	-	0.08	tr	tr	0.46	0.37	3.75	0.26	0.22	0.50
30	----	-	-	0.10	tr	tr	-	-	-	-	-	0.34
31	nerolidol	MS-GC	-	0.27	2.50	3.69	0.85	0.86	15.98	0.65	0.90	3.64
32	----	-	-	-	tr	tr	-	-	-	-	-	-
33	terpenyl acetate	MS-GC	-	0.11	0.09	0.09	-	-	0.50	-	-	-
34	sesquit. alcohol 222	MS	-	1.20	1.77	2.43	-	-	0.28	-	0.09	0.14
35	sesquit. MW 220	-	-	-	-	-	1.01	-	-	0.65	0.10	0.34
36	α-bisabolol	MS-GC	-	14.64	14.34	10.72	1.45	0.94	4.37	0.81	1.20	3.25
37	----	-	-	0.06	tr	tr	0.41	-	0.94	0.39	0.40	0.56
38	----	-	-	0.33	tr	tr	-	-	0.60	-	0.41	0.43
39	----	-	-	-	0.06	0.20	0.08	1.62	-	-	-	-
40	----	-	-	0.50	tr	tr	0.14	3.77	1.20	0.52	0.73	0.84
41	----	-	-	0.61	tr	tr	1.94	-	5.17	0.97	0.70	3.08
42	----	-	-	0.39	0.45	0.79	0.30	-	3.90	0.10	0.23	1.00
43	----	-	-	-	0.16	0.35	-	-	2.60	-	0.25	1.52
44	----	-	-	0.12	0.42	0.87	0.24	-	-	0.65	0.25	-
45	----	-	-	-	tr	tr	0.18	-	4.05	0.60	-	1.20
46	----	-	-	-	tr	tr	3.04	1.32	1.62	1.94	1.05	1.90
47	----	-	-	-	tr	tr	1.21	-	0.32	0.17	0.15	1.12
48	----	-	-	-	tr	tr	2.13	1.98	2.25	1.20	0.93	3.08
49	----	-	-	7.48	1.34	1.00	-	-	-	-	-	-

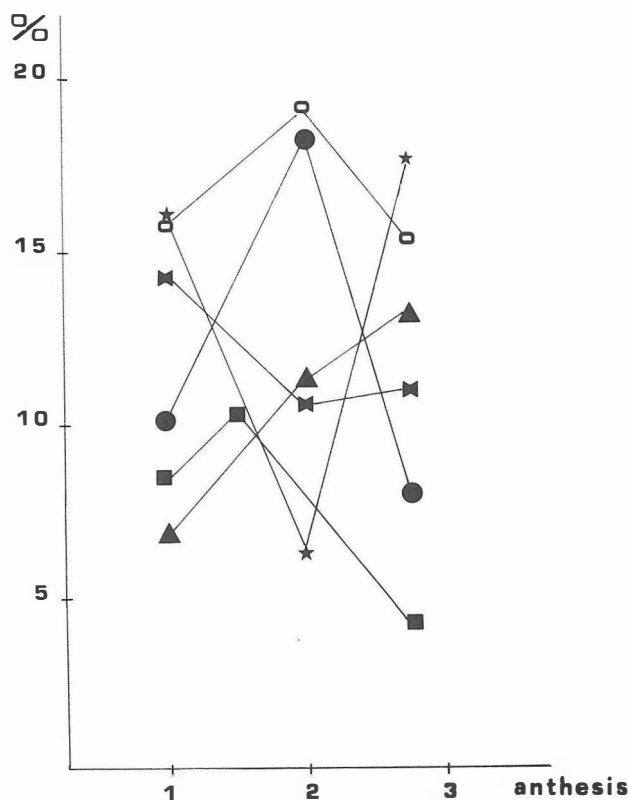


Fig. 1 — Variation of 1,8-cineole (○), α -bisabolol (◄), isoborneol (■), borneol (▲), α -thujone (*) and β -caryophyllene (●) content in *S. officinalis* during the anthesis.

characterized primarily by high percentages of β -caryophyllene and α -thujone.

Closely related with the anthesis are borneol, β -bisabolene and δ -cadinene, which strongly decrease. The percent variation of some main components during anthesis is visualized in some graphs (fig. 1-3). All the taxa always show a high percentage of α -thujone than β -thujone in all phases of anthesis. Essential oil yields from the genus *Salvia* species showed wide inter-specific variation (Table 2).

Table 3 shows the main groups of terpene derivatives.

The two *Salvia officinalis* populations are very similar and differ only for the percentages of monoterpene hydrocarbons and of 1,8-cineole. *S. bertolonii* and *S. verticillata* have essential oils of very similar composition; they differ from *S. officinalis* for their smaller percentage of oxygenated monoterpenes and sesquiterpenes, of camphor and 1,8-cineole. In addition they show a percentage almost 3 times higher of sesquiterpene hydrocarbons. Alpha- and beta-thujone are more abundant in *S. bertolonii* and *S. verticillata*.

Some components of the essential oils seem to significantly characterize the

Table 2 — Mean terpene percentage composition of essences of *Salvia* species.

N. Compounds	A'	A	B	C
1 α -thujene	-	0.11	0.10	0.12
2 α -pinene	0.07	1.92	0.22	0.28
3 camphene	0.06	3.27	-	0.03
4 β -pinene	0.27	1.97	0.51	0.46
5 myrcene	0.06	0.35	0.02	0.11
6 α -phellandrene	-	0.01	-	-
7 1,8-cineole	4.78	16.48	0.27	0.93
8 limonene	-	0.67	0.09	0.28
9 α -terpinene	-	-	-	-
10 p-cimene	0.27	0.13	-	-
11 γ -terpinene	-	-	-	-
12 ox.monot.MW 152	-	-	0.26	0.49
13 α -thujone	12.59	13.31	18.57	16.04
14 β -thujone	4.66	1.91	3.79	3.80
15 linalyl acetate	0.41	-	-	-
16 camphor	2.64	3.89	0.68	0.48
17 linalool	1.24	1.38	0.82	0.78
18 bornyl acetate	0.78	4.33	-	-
19 β -caryophyllene	8.29	12.50	26.62	28.44
20 terpinen-4-ol	0.43	0.02	0.16	-
21 isoborneol	6.51	6.41	2.86	4.22
22 borneol	24.12	10.45	15.16	24.16
23 β -bisabolene	1.98	0.01	3.03	2.01
24 carvone	-	-	-	-
25 δ -cadinene	4.28	0.67	2.20	2.81
26 myrtenol	0.43	-	-	-
27 calacorene	0.14	-	0.32	0.09
28 ----	0.10	-	-	-
29 ----	0.08	-	1.52	0.32
30 ----	0.10	-	-	0.11
31 nerolidol	0.27	2.32	5.89	1.72
32 ----	-	-	-	-
33 terpenyl acetate	0.11	0.06	0.16	-
34 sesquit.alcohol 222	1.20	1.63	0.93	0.07
35 sesquit.MW 220	-	-	0.33	0.36
36 α -bisabolol	14.64	12.02	2.25	1.75
37 ----	0.06	-	0.45	0.44
38 ----	0.33	-	0.19	0.28
39 ----	-	0.32	0.56	0.08
40 ----	0.50	-	-	0.69
41 ----	0.06	-	-	1.58
42 ----	0.39	0.62	1.39	0.44
43 ----	-	0.30	0.86	0.58
44 ----	0.12	0.50	0.08	0.29
45 ----	-	-	-	-
46 ----	-	-	-	-
47 ----	-	-	-	-
48 ----	-	-	-	-
49 ----	7.48	0.94	-	-

examined populations. The best combinations of terpenoid characters are reported in some triangular graphs, shown in fig. 4. It is evident that borneol, isoborneol and nerolidol are the terpenes that best discriminate the three taxa. It is to be noted that borneol, isoborneol, nerolidol are all oxygenated terpenes with an alcoholic group. In the space defined by chemical variables, taken three by three, the taxa are

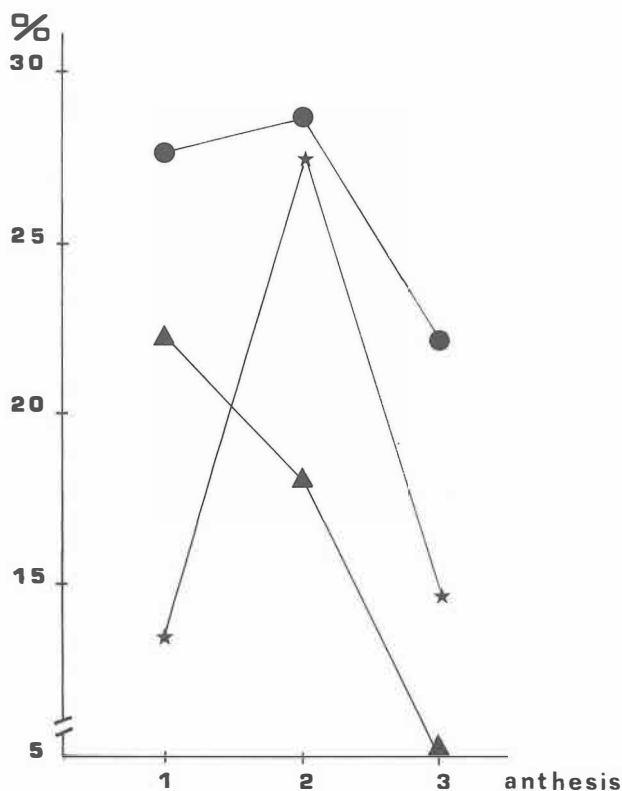


Fig. 2 — Variation of α -thujone (*), β -caryophyllene (●) and borneol (▲) content in *S. bertolonii* during the anthesis.

clearly identifiable and sufficiently isolated. A' population from Dalmatia is an obviously very close position to A population from the Karst Plateau. The terms borneol, α -bisabolol, β -caryophyllene put the A taxon in a more isolated position and accomunate B and C taxa.

Table 4 shows the percentages of the monoterpene derivatives, which allow the identification of each taxon. *S. officinalis* is recognized by percentages of α -bisabolol $\geq 15.16\%$ and 1,8 cineole $\geq 0.83\%$; *S. verticillata* by percentages of borneol $\geq 15.16\%$; *S. bertolonii* by percentages of nerilidol $\geq 2.32\%$. All terpene derivatives (markers) are oxygenated, in particular alcohols.

In order to visualize the chemical relationship among the taxa, dissimilarities were computed (Table 5) and a multivariate analysis was performed. The two clusters of the dendrogram (fig. 5) join together the most similar populations. In the first cluster the two *S. officinalis* populations are joined at high similarity; in the second *S. bertolonii* and *S. verticillata* are joined at a high degree of similarity. The clusters are linked by a very low degree of similarity.

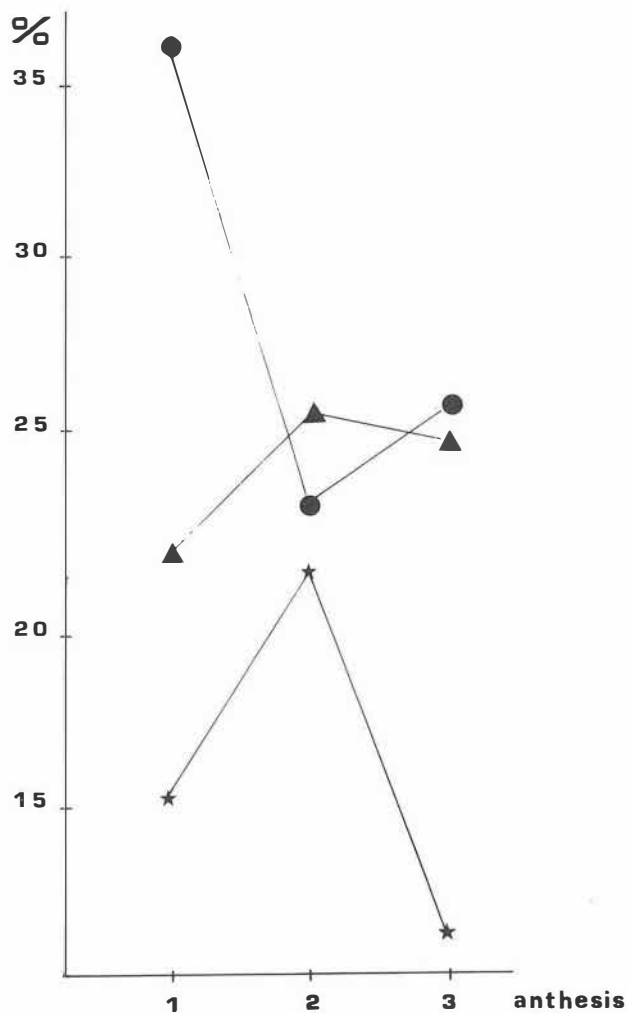


Fig. 3 — Variation of α -thujone (*), β -caryophyllene (●) and borneol (▲) content in *S. verticillata* during the anthesis.

Discussion

A study of the occurrence of various monoterpenes in some other *Salvia* species (*leucophylla*, *mellifera*, *spathacea* and *apiana*) from different localities was carried out to determine their usefulness as taxonomic characters and as markers for studies of hybridization and introgression (Emboden & Lewis, 1967). Other attempts were made to relate terpene content to taxonomy in various groups of plants (Swain, 1963a, 1963b; Alston & Turner, 1963; Hegnauer, 1962) especially after the advent of modern and sophisticated methods of analysis. Therefore the

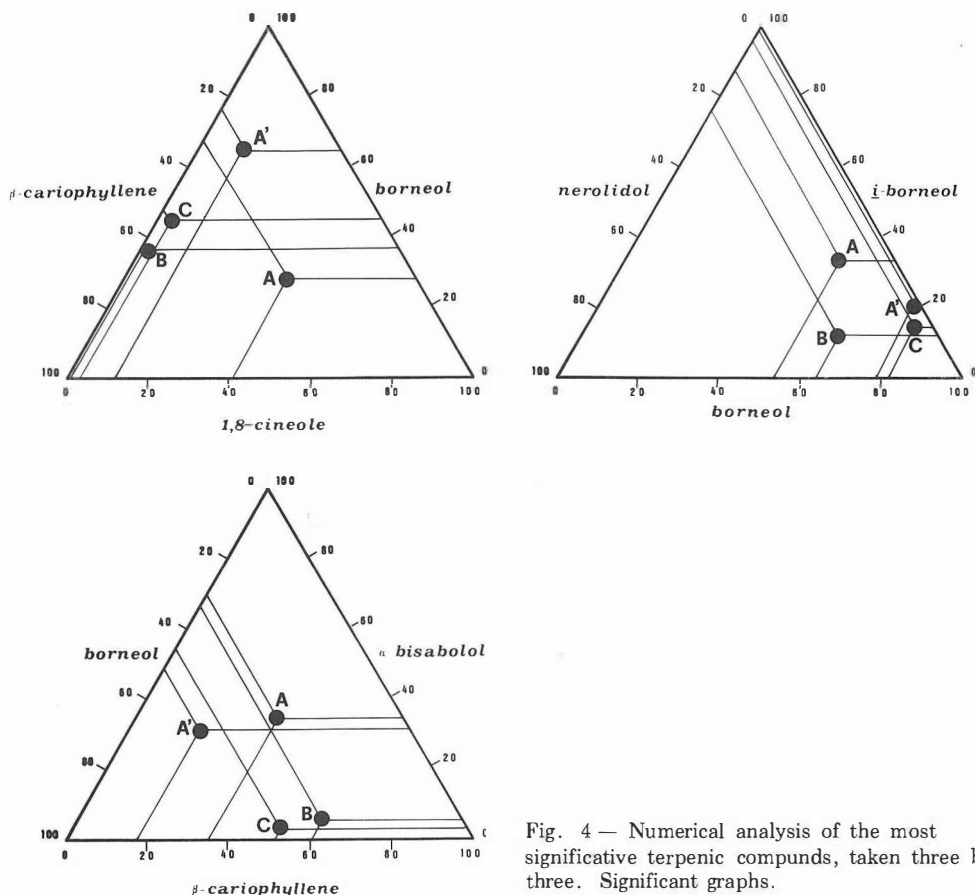


Fig. 4 — Numerical analysis of the most significant terpenic compounds, taken three by three. Significant graphs.

purpose of this study was to provide a new set of characters that might further clarify inter-specific relationships.

The difference in terpene content between species primarily concerns the relative abundance of the various terpenes rather than the presence or absence of a given compound. However each species has a characteristic terpene composition that permits its identification on the basis of chemical data. Statistical comparison of chemical data demonstrates the validity of chemical markers for taxonomic purposes.

In our study quantitative differences in essential oils carried taxonomic value at the level of species. The classification of the three taxa on a chemical basis confirms the morphological classification. Biosyntheses of some terpenes seem to occur in more immature foliage while conversion into derivative terpenes occurs in older foliage. Our results showed some significant differences between young and older leaves: in *S. officinalis* older leaves, borneol and bornyl acetate increase, while camphor decreases and finally disappears. Camphor is presumably a breakdown

Table 3 — Terpene pattern groups and main components present in the *Salvia* populations.

Terpene groups	A'	A	B	C
Monoterpene hydrocarbons	1.42	8.57	1.07	1.63
Oxygenated monoterpenes	66.99	58.60	42.73	51.09
Sesquiterpene hydrocarbons	14.69	13.18	32.17	33.35
Oxygenated sesquiterpenes	15.84	13.65	3.18	1.82
Acyclic sesquiterpenes (nerolidol)	0.27	2.32	5.89	1.72
$\alpha + \beta$ thujone	17.25	15.22	22.36	19.84
Camphor	2.64	3.89	0.68	0.48
1,8-cineole	4.78	16.84	0.27	0.93

product or the result of an interconversion; the variation of the former is probably related to the distribution of morphologically different trichomes. Three types of trichomes are predominant in this species: capitate, nonglandular and peltate. The oil is produced by the glandular trichomes, which are small and scarce in the young leaves. Their number increases with the ontogenetic cycle. As the anthesis proceeds the contents in monoterpene hydrocarbons tend to increase (Corsi et al., 1982) and correspondently the content in oxygenated terpenes decreases. In *S. officinalis* a certain biogenetic interdependence with inversed correlation among 1,8-cineole, β -cariophyllene, isoborneol and α -thujone and among borneol and α -bisabolol was noted. In *S. verticillata* and *S. bertolonii* there seems to be an inversed correlation between the biosynthesis of borneol and β -cariophyllene.

Table 4 — Terpene components for the characterization of *Salvia* populations.

	A	C	B
1,8-cineole	16.84	0.93	0.27
α -bisabolol	12.02	1.75	2.25
borneol	10.45	24.16	15.16
nerolidol	2.32	1.72	5.87

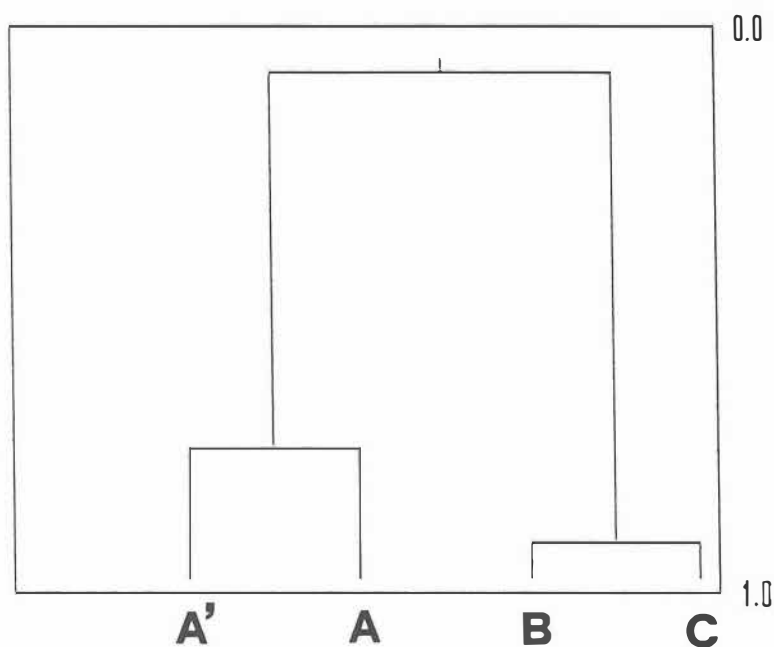


Fig. 5 — Dendrogram of terpene similarities among *Salvia* species. Similarities based on Jaccard coefficients.

Table 5 — Dissimilarity coefficients based on terpenoids profiles of *Salvia* species.

	A'	A	B	C
A'	0	21.4968	27.2843	25.9968
A		0	26.6700	29.6493
B			0	10.9273
C				0

The biogenetic interdependence between β -thujone and borneol in *S. officinalis* has already been noted (Poldini et al., 1971; Corsi et al., 1982), whereas the correlation between 1,8-cineole and thujones has been never recorded. All the taxa show a high percentage of thujones, well-known substances of high toxicity (epileptic action). Thanks to the significant chetonic fractions, present in all taxa, they would act as remarkable stimulants, vermifuges, antispasmodics. The taxon poorer in chetones and richer in hydrocarbons should be able to perform an anhydrotic action (Duquenois, 1972).

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Riassunto

Le foglie di alcune specie spontanee di *Salvia* L. sono state raccolte in tre momenti dell'antesi e il loro olio essenziale è stato analizzato mediante GC/GCMS. La composizione terpenica è molto variabile durante l'antesi. *S. bertolonii* è la specie più ricca in α -tujone; *S. officinalis* è caratterizzata da alte percentuali di 1,8-cineolo, 4-terpineolo, isoborneolo e α -bisabololo; in *S. verticillata* sono presenti alte percentuali di borneolo e β -cariofillene. In tutte le tre specie, l' α -tujone è presente in quantità nettamente superiori al β -tujone. I tre taxa sono individuabili sulla base di specifiche combinazioni di derivati terpenici. L'analisi multivariata dei dati chimici ha consentito di individuare il grado di affinità tra i tre taxa e di chiarire il loro status chemotassonomico. Alcuni componenti terpenici dell'olio di *Salvia* hanno interessanti proprietà farmaceutiche.

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DISTRIBUTION AND PHYTOSOCIOLOGICAL BEHAVIOUR OF MOEHRINGIA TOMMASINII MARCH.

Fabrizio MARTINI

Keywords. *Moehringia tommasinii* March, Chorology, Ecology, Phytosociology.

Abstract. This paper deals with the distribution, ecology and phytosociology of *Moehringia tommasinii* March., a stenoendemic species that occurs at the border between Italy and Yugoslavia, near Trieste. A new phytocoenosis of the submediterranean limestone rocks in the North-Adriatic area is described: *Asplenio-Moehringietum tommasinii* (Centaureo-Campanulion), which is characterized by *Asplenium lepidum* and *Moehringia tommasinii*.

Historical Introduction

"Hence I don't believe it inappropriate to consider our *Moehringia* as a good species, adorning it with the name of my revered, unforgettable teacher Muzio de Tommasini, who can, with reason, call himself the Father of our Flora".

This is how Carlo Marchesetti (1880a), with the affectionate devotion of the favourite pupil towards his Mentor, who had died shortly before, entrusted *Moehringia tommasinii* to botany, associating, maybe unknowingly, but with a happy combination, the names of the Fathers founders of Trieste's Flora to a very noble vegetable stock (1).

In reality, Tommasini had already collected the plant in 1843 on the cliffs overhanging S. Sergio/Černikal (TSM!) attributing it in a first time to *M. muscosa* L. var. *firma* Tomm., successively to *M. ponae* Fenzl, a name with which it even appears in Loser (1860) and finally, since 1864, to *M. glaucovirens* Bertol. (Tommasini, in sched., TSM!; Tommasini, 1865).

Even different and more articulate were Freyn's conclusions (1876) who, through a meticulous analysis of the samples sent him by Tommasini, and supported by acute considerations on the tendency of the genus to segregate punctiformal endemisms, thought them belonging to a not yet described species;

but, still doubtful, he preferred to ascribe them to *M. sedifolia* Willd.

On the other hand, the idea that it could be a new entity wasn't entirely new to Tommasini himself who expressed it in a correspondence with Parlatore (Marchesetti, 1880b).

Only in 1880 was it described as an autonomous species by Marchesetti (1880a) who, beside the description, wrote an accurate diagnosis towards *M. glaucovirens*, *M. sedifolia*, *M. bavarica* (\equiv *M. ponae* [Rchb.] Fenzl) and secondly towards *M. papulosa* (Marchesetti, 1909).

Systematics and Chorology

Moehringia tommasinii belongs to a complex of closely related species including *M. bavarica* (L.) Gren. of the Southern calcareous Alps (Stiria, Bosnia-Erzegovina, Serbia up to the Northern Albany: Sauer, 1965), *M. papulosa* Bertol. of the Appennine of the Marche, Furlo Gorge (Bertoloni, 1841), and *M. provincialis* Merxm. & Grau of the Provençal Alps (Merxmüller & Grau, 1967).

We're dealing with a cycle of forms mostly with tetrameric flowers (only *M. bavarica* has pentameric flowers), having seeds with a well developed strophiole, constituted of slender and elongated cells (Merxmüller & Grau, cit.).

It is well known that the major part of the European *Moehringiae* are stenoendemic remains with a punctiform distribution, widespread along the peripheric circum-mediterranean chains (Merxmüller & Gutermann, 1957; Sauer, 1959 and 1965; Halliday, 1964; Friedrich, 1969).

Even ours is a stenoendemic species ($2n = 24$, Grau, 1964) whose range, quite limited, comprises a minuscule swarm of stations aligned along the Western chains of Vena mountains (Northern Istria) (Martini, 1987).

According to Pospichal (1897), resumed by Ascherson & Graebner (1919) and by Mayer (1960), the area would extend in the heart of Mountainous Istria (Cicceria), up to Pinguente/Buzet and indeed "...wahrscheinlich langs der unteren Terrassen des Cican-Bodens noch öfter." (Pospichal, cit.).

For this area, in spite of repeated investigations on the spot, we're only able to reconfirm the station listed in Marchesetti (1896-'97), situated between Val Rosandra (the only Italian location) and Popecchio/Podpeč (fig. 1); even E. Mayer (in litt., 1988) writes: "Die beiden erstgennanten Fundorte (S. Sergio/Černikal and Popecchio/podpeč, n.d. r.) habe ich seinerzeit selbst aufgesucht, während mir die beiden letzten (Nugla and Berda near Pinguente/Buzet) nur aus der Literatur bekannt sind."

On the other hand, it appears noteworthy the recovering of the endemic species at Bagni of S. Stefano/Istarske Toplice, where it was collected in 1900 by Marchesetti (FI!), but this finding was never published. This is the most Western station, isolated with respect to the main range that, nevertheless, hosts a particularly numerous population, settled at the base of the big rocky walls that overhang the Istrian thermal resort.

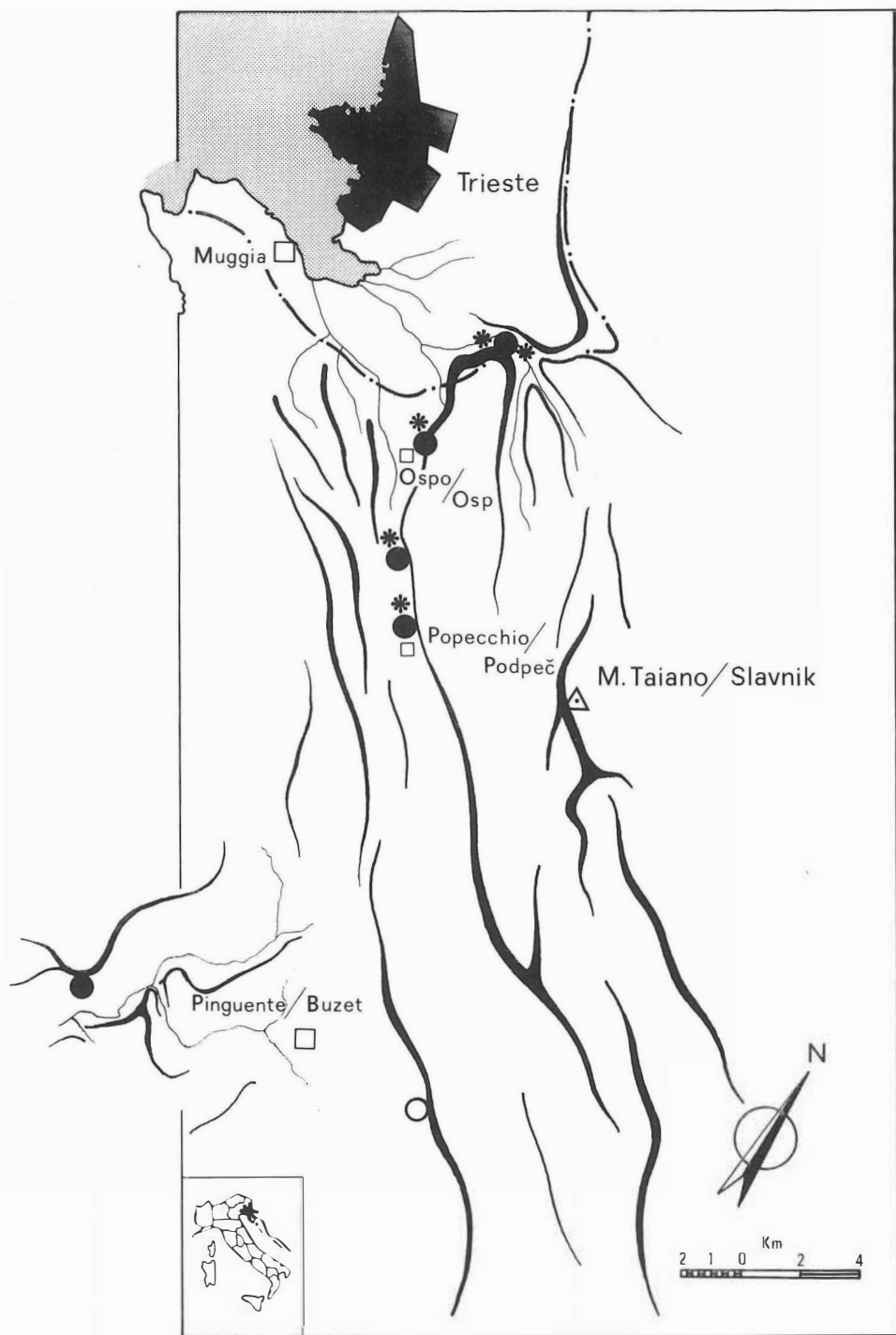


Fig. 1 — Range of *Moehringia tommasini* (● herbarium data; ○ bibliographic data) and *Asplenium lepidum*'s stations (*) in the considered area.

Exsiccata visa

Moehringia tommasinii March.

Syn.: *M. muscosa* L. var *firma* Tommasini; *M. ponae* Loser, non Fenzl; *M. glaucovirens* Tommasini, non Bertol.; *M. sedifolia* Freyn, non Willd.; *M. bavarica* (L.) Kern. var. *tommasinii* March.

Rupi sopra Černikal, 4-16.VI.1843, sub *M. muscosa* var. *firma* (TSM) (2); Černikal, 5-16/17.VI.1843, sub *M. ponae* Fenzl (TSM); sopra Bolunz, 10-25. IV. 1844 (TSM); rupi presso Bolunz, 9-10.V.1844 sub *M. ponae* (TSM); rupi all'ingresso della grotta di Ospò, 3-14 (?). III.1862, sub *M. ponae* (TSM); pareti di rupi all'ingresso della grotta di Ospò, 8-30.V.1863, sub *M. ponae* (TSM); grotta di Ospò, ingresso, 2-10.VII.1864, sub *M. glaucovirens* (TSM); muri di chiusa della grotta di Ospò, 7-10.VII.1864, sub *M. glaucovirens* (TSM); grotta di Ospò, 1-5.VI.1865, sub *M. glaucovirens* (TSM); Fentes de rochers et des murailles de la grotte d'Ospò, en Istria, près de Trieste, Tommasini (ex herb. Schultz); muri della grotta di Ospò, 6-13.V.1875, Marchesetti (?), sub *M. sedifolia* (TSM); Istria, Ospò, V.1881, Marchesetti (FI); Trieste, sulle mura della grotta di Ospò, VI.1881, Marchesetti (FI); Trieste, Ospò, VI.1895, IV.1913, V.1915, V.1922, Marchesetti (FI); Trieste, Ospò, V.1914, Marchesetti (TSB); Trieste, all'antro di Ospò (l. cl.), VI.1909, IV.1913, IV.1923, Marchesetti (FI); Istria, rupi di S. Stefano al Quieto, IV.1900, Marchesetti (FI); in agro tergestino, in fissuris rupium ad Balneolim (Bolunz) et Cernical prope Tergestum et in rimis muri diruti ante antrum Osposense in ditone Justinopolitana in Istria, Marchesetti, Fl. Exsicc. Austro-Hungar. (TSB, FI); Justinopolis (hodie Capodistria), in rimis muri diruti et in rupium fissuris prope antrum Osposense, alt. m 100, solo calcareo, Jun 1908, Marchesetti, Sched. Fl. Ital. Exsicc. (FI); grotta di Ospò, 9.VI.1922, Vatova (FI); pareti all'entrata della grotta di Ospò, 3.VIII.1963, Lausi (TSB); antro di Ospò, 21. IV.1967, Poldini (TSB); antro di rio Ospò, 1. X.1967, Gomisel (TSB); antro di Ospò (Trieste), 17.V.1970, Poldini (TSB); Flora Italiae-prov. Trieste: Val Rosandra, vers. S-SW del crinale, rupi a lato del sentiero, m 150-280, 17.VIII.1987, F. Fenaroli (TSB); Val Rosandra, rocce del crinale (Jugove stene), m. 180-250, loc. classicus, 22.VIII.1987, Poldini (TSB); Flora Sloveniae: contrafforti SW del Vrh Stene, sopra la strada Podpeč-Črnotice, m 320, 14.V.1988, Martini (TSB); Flora Sloveniae: Črni Kal, m 350, 19.V.1988, Martini (TSB); Flora Croatiae: Istria, Bagni di S. Stefano-Istarske Toplice, m 40, 20.I.1989, Martini (TSB).

Ecology

Like many congeneric species, even *Moehringia tommasinii* is typically chasmophytic, and vegetates on vertical or subvertical cliffs of the submediterranean strip between 100 and 350 meters above sea level. The lithosoils are in general nummulithic limestones of the lower Eocene.



Fig. 2 — Habitat of *Moehringia tommasini* at S. Sergio/Černikal (Jugoslavia) (Photo E. Osualdini).

For the most part, the stations are found aligned along a series of chains that constitute the highest embankment of Istria's Karst and, at the base, are in contact with arenaceous formations of the upper Eocene.

The station's exposition is mostly southern, with a higher frequency on South-western slopes, shielded from the bora.

The plant preferably occurs along the edges of the big niches found at the base of rocky walls in a position sheltered from rain (fig. 2). In favourable habitats the cushions reach the maximum development assuming the form of festoons that can reach extents of half a meter.

We can observe the tendency to exploit the hydric percolation veins of the limestones, which evidently guarantee both the hydric and the nutrients' supplies.

Moreover, we ascertained that transplant experiments have given the best results when the plant was put in niches protected from direct drip.

Thus, in conclusion, *Moehringia tommasinii*, even showing psycrophytism, recoils from direct contact of the aerial parts with water, especially if this contact is violent.

As far as soils are concerned, these are always more or less compact vertical rocks that evidently offer the plant, whose dissemination, like in all *Moehringiae*, is myrmecochore, its major changes.

Asplenio-Moehringietum tommasinii ass. nova

	1	2	3	4	5	6	7	8	9		
numero progressivo	1	2	3	4	5	6	7	8	9		
altitudine (m s.l.m.)	350	150	360	170	325	325	100	95	100	presenza	classe di frequenza
inclinazione (°)	90	90	90	90	>90	>90	90	90	>90		
esposizione	SW	SW	SW	SW	W	SW	NW	SE	SE		
superficie (mq)	150	100	150	100	100	100	200	100	200		
n° specie per rilievo	13	12	9	12	8	11	9	11	4		
Specie caratt. dell'assoc.											
Moehringia tommasinii March.	1	1	1	+	1	+	1	+	1	9	V
Specie caratt. di alleanza (Centaureo-Campanulion)											
Sesleria juncifolia Suffr. var. interrupta Vis.	+	+	+	1	+	1	1	1	.	8	V
Campanula pyramidalis L.	+	+	+	.	+	+	+	+	.	7	IV
Micromeria thymifolia (Scop.)Fritsch	+	+	+	+	.	.	.	.	.	4	III
Euphorbia fragifera Jan	.	.	.	.	+	+	.	.	.	2	II
Specie caratt. di ordine e classe (Asplenietalia glandulosi (*), Asplenietea rupestris)											
Asplenium lepidum K.Presl (*)	+	+	+	+	+	+	.	.	.	6	IV
Teucrium flavum L. (*)	.	.	.	.	.	.	+	+	.	2	II
Asplenium trichomanes L.	.	.	.	.	.	.	.	.	+	1	I
Ficus carica L. (*)	.	.	.	.	.	.	.	.	+	1	I
Silene saxifraga L. (*)	.	.	.	+	.	.	.	.	.	1	I
Specie compagne											
Parietaria diffusa Mert. & Koch	1	+	1	+	+	+	+	1	+	9	V
Satureja variegata Host	+	+	+	1	+	+	+	+	.	8	V
Coronilla emerus L. subsp. emeroide (Boiss. & Sprun.)	+	.	.	+	.	+	+	+	.	5	III
Petrorrhagia saxifraga (L.) Lk.	.	.	+	.	.	+	.	+	.	3	II
Catapodium rigidum (L.) C.E.Hubb	.	+	.	+	.	.	.	.	.	2	II
Galium lucidum All.	.	.	.	.	.	+	.	+	.	2	II
Seseli gouanii Koch	+	.	.	.	.	.	+	.	.	2	II
Sedum album L.	.	.	.	.	.	.	+	+	.	2	II
Alyssum montanum L.	.	.	+	.	.	.	.	+	.	2	II
Daphne alpina L.	.	+	.	+	.	.	.	.	.	2	II
specie sporadiche	4	3	.	2	1	1	.	.	.		

It seems that the severity of the environment favours these species even in an indirect way, eliminating concurrent plants. We observed that compact and overhanging walls, fresh because exposed to the East, as they occur at the bottom of Ospo/Osp's Cavern, accept, beside the dominant cushions of *Moehringia*, very few other species such as *Ficus carica* and *Asplenium trichomanes* (rel. 9). On the contrary, on thicker, more friable, less inclined (70-80 degrees) limestone layers, where erosion is more intense, the presence of other species such as *Sesleria juncifolia* (2), *Campanula pyramidalis*, *Parietaria judaica*, *Satureja variegata* establishes a regime of major competition that *Moehringia tommasinii* cannot withstand. In this case, the number and dimensions of the specimens tend to decrease directly with respect to the entry of new species.

The presence and the exuberance of the endemic species are conditioned by the superficial morphology of the walls, by the exposure and by the hydric supply.

Floristical Characteristics

The *Asplenio-Moehringietum tommasinii* is a chasmophytic coenosis of the submediterranean strip, which develops between 100 and 300 meters above sea level. It is characterized by the constant presence of *Moehringia tommasinii* (cl. freq. V) faithfully accompanied by *Sesleria juncifolia* var. *interrupta* (V) (3) and *Campanula pyramidalis* (IV).

To these is associated *Asplenium lepidum* (IV), a small ombrophobic fern (2n=144, Meyer, 1959) whose range is centered in South-eastern Europe (Jalas & Suominen, 1972; Brownsey, 1976), on the mountains of North-eastern Italy (Hauser in Poldini, 1966; Ferrarini & al., 1986) and of Yugoslavia (Beyer, 1884; Mayer & Horvatič, 1967) up to Serbia (Mayer & Diklič, 1971), with considerable populations in Austria (Melzer, 1962), Roumania and disjunctions scattered in France, Southern Italy, Albania, Macedonia and Crete, where it reaches its Southern limit (Brownsey, 1976).

Being a chasmophytic community, it harbours a limited number of species, averaging 10 per relevé, among which *Parietaria diffusa* (V) and *Satureja variegata* (V) were never lacking. The latter could be considered as an illyric entity (Feoli & Poldini, 1979) but we preferred to emphasize its phytoclimatic indicator value counting it as an Euro-mediterranean species given its attribution to *Thero-Brachypodietea*.

In some cases, the lichen component assumes a particular importance with the presence of *Fulgensia fulgida* (Nyl.) Szat., *Gonohymenia nigritella* (Lettam) Hensen, *Lecidea* (= *Psora*) *lurida* (With.) Ach., *Squamarina cartilaginea* (With.) P. James, *Squamarina gypsacea* (Sm.) Poelt; these are all xerothermic elements with an essentially steppic distribution extending to the mediterranean area and to the most arid parts of Central Europe (Nimis & Loi, 1982).

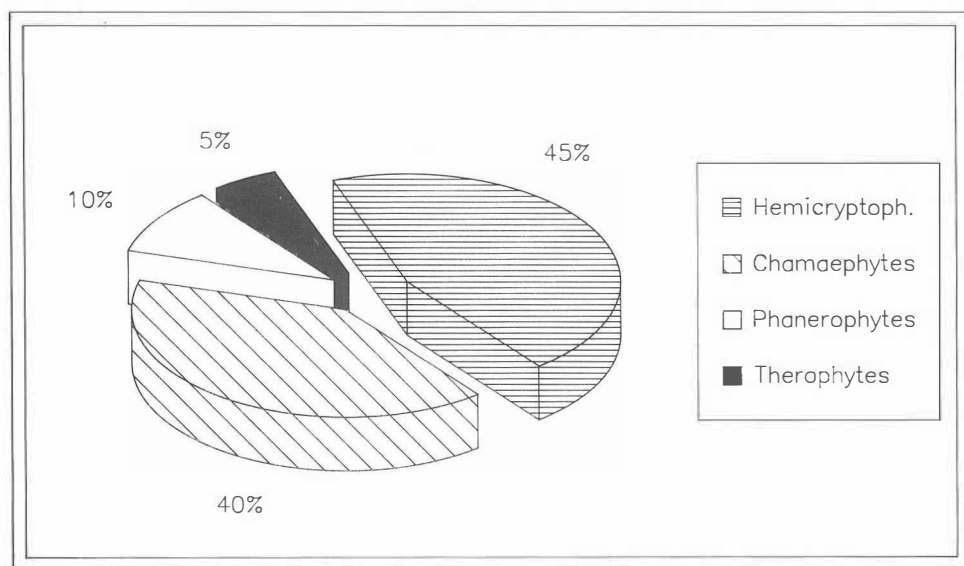


Fig. 3 — Biological spectrum of *Asplenio-Moehringietum tommasinii*.

Syntaxonomic Considerations

The association of *Asplenium lepidum* to *Moehringia tommasinii* to identify this coenosis has a double meaning, even if the fern has, as it was seen, a broader distribution extended to South-eastern Europe. On one hand it tends to emphasize the ecological affinities that bind the two species in the territory under study, considering that even *Asplenium lepidum* is a highly specialized ombriphobic chasmophyte... "being restricted entirely to limestone rock and growing only where competition from other species is at minimum" (Brownsey, 1976); on the other hand it tends to underline floristic systematic bonds to *Asplenietalia petrarchae* and therefore to the vegetation of mediterranean cliffs.

Concerning this subject, we wish to point out that the systematics that we adopted, already hinted to by Poldini (1989) follows the laying down of Horvatič (1934, 1939, 1963), which inserts the chasmophytic vegetation of the northern Adriatic coast in the endemic alliance *Centaureo-Campanulion*, belonging to *Asplenietalia petrarchae*.

In 1980, Trinajstić dismembered this order with the creation of the *Centaureo-Campanuletales* which gathers together all the rock-linked associations of the Adriatic belonging to the Mediterranean region. However, in doing this, the sinusya of species characteristic of *Centaureo-Campanulion* sensu Horvatič becomes noticeably impoverished and at the same time other entities such as *Centaurea* sect. *Pterolophus* and *Campanula* sect. *Garganicae* are introduced, which don't appear in our relevés, where, on the contrary, the species of Horvatič alliance are well represented.

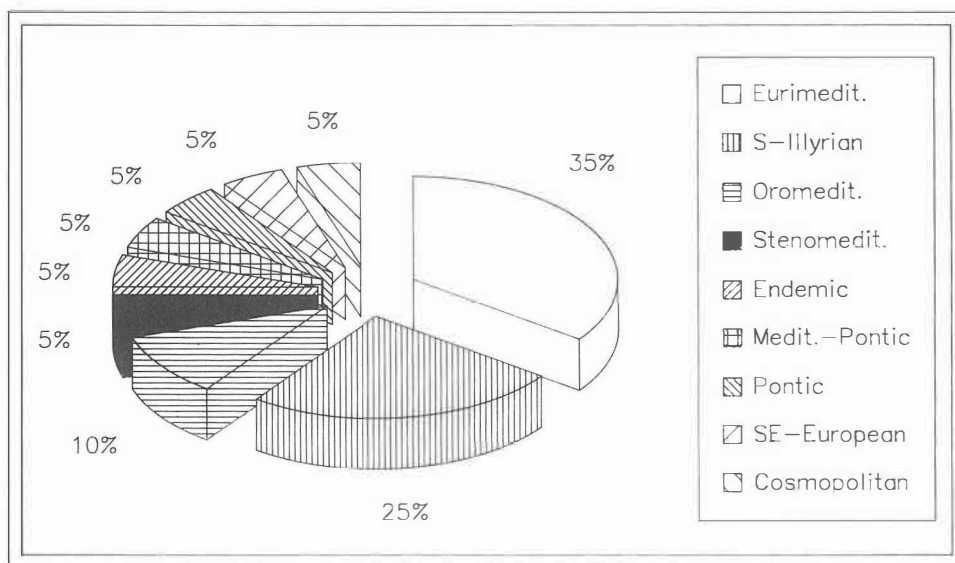


Fig. 4 — Chorologic spectrum of *Asplenio-Moehringietum tommasinii*.

Biology

The biological spectrum (fig. 3) evidentiates the relevant participation of the hemicryptophytes (45%) and of the chamephytes (40%) that usually mark the chasmophytic associations and which find ample verification in the values furnished by Lausi & Poldini (1962) for the *Saturejo-Euphorbietum wulfenii* of Trieste's coastline.

On the chorological level (fig. 4) the mediterranean element prevails (40%), followed by the Southern-illiric (25%) and by oromediterranean elements (10%). The *Asplenio-Moehringietum tommasinii* still conserves a true mediterranean imprint in which the illiric element, constituting the floristic distinguishing mark of the Northern Adriatic Karst territories, is less frequent; the central-European and Eurosiberian phytogeographical elements, which dominate in the climacic or paraclimacic formations of these latitudes, are absent in this community. This confirms the refugial role played by primitive biotopes, for plants growing at the limits of their ranges (Poldini, Martini & Pertot, in publ.); such environments can give way to phenomena of insularity that substract them from the regional phytogeographical traits. Not by change, these associations host the endemic elements linked to oligotrophic soils.

Concluding remarks

The graph of fig. 5 compares *Asplenio-Moehringietum tommasinii* with the principal chasmophytic associations of the North-eastern Adriatic coast and pre-

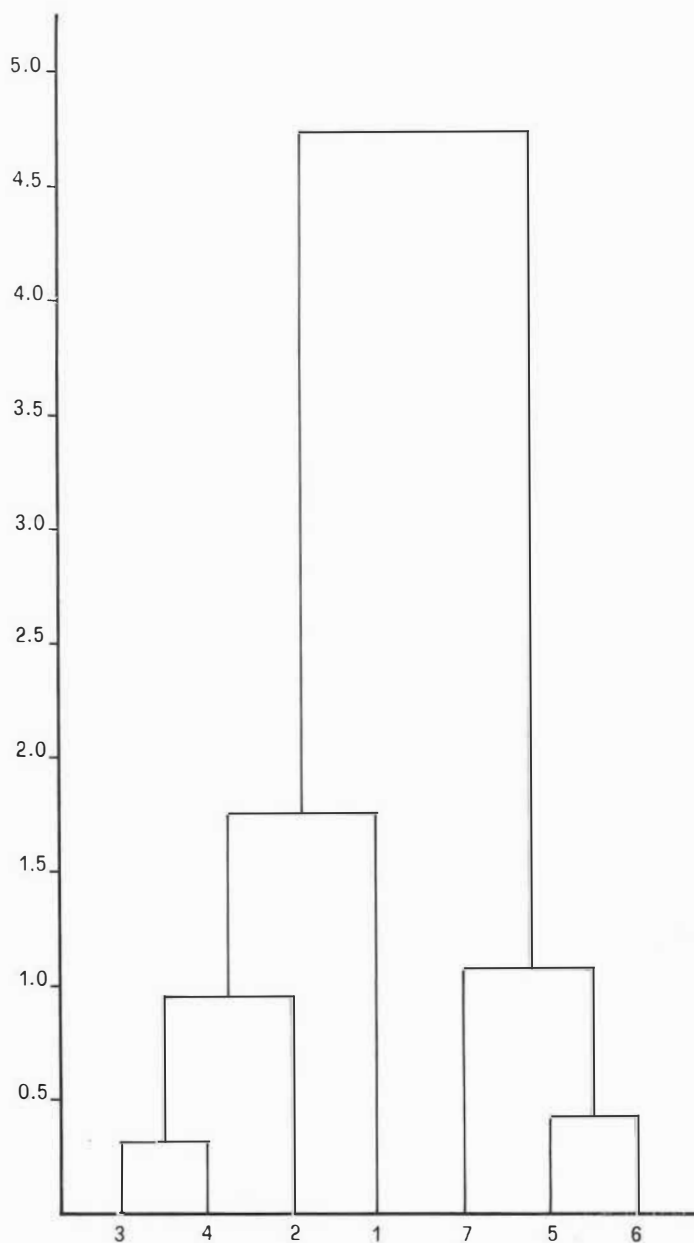


Fig. 5 — Affinity dendrogram between *Campanulo-Centaureetum dalmaticae* (1), *Campanulo-Centaureetum kartschianae* (2), *Saturejo-Euphorbietum wulfenii* (3), *Asplenio-Moehringietum tomasinii* (4), *Phyteumato-Potentilletum caulescentis* (5), *Spiraeo-Potentilletum caulescentis* (6) and *Arenarietum huteri* (7).

Alpine chains. This comparison is based on the numeric classification of the following phytocoenoses (in parenthesis the number of relevés considered for each of these and the source from which they were derived):

A. All. *Centaureo-Campanulion* H-ič (34) 37

1. *Campanulo-Centaureetum dalmaticae* H-ič (34) 37 (17 relevés; Horvatič, 1934 and 1939; Trinajstić, 1965)

2. *Campanulo-Centaureetum kartschianae* Lausi & Poldini 62 (8 relevés; Lausi & Poldini, 1962)

3. *Saturejo-Euphorbietum wulfenii* Lausi & Poldini 62 (5 relevés; Lausi & Poldini, 1962)

4. *Asplenio-Moehringietum tommasinii* ass. nova (9 relevés)

B. All. *Potentillion caulescentis* Br.-Bl. in Br.-Bl; & Jenny 26

5. *Phyteumato-Potentilletum caulescentis* Poldini 78 (14 relevés; Poldini, 1978)

6. *Spiraeo-Potentilletum caulescentis* Poldini 73 (20 relevés; Poldini, 1973)

C. All. *Cystopteridion* Rich. 72

7. *Arenarietum huteri* Poldini & Martini 76 (30 relevés; Poldini & Martini, 1976).

We also inserted the relevés of *Potentillion caulescentis* and *Cystopteridion* alliances not as much as to remark an obvious diversity with respect to those of the *Centaureo-Campanulion*, but to evidentiate the syntaxonomic relations of the chasmophytic coenoses occurring between the sub-mediterranean and the mountain belts of the region.

The dendrogram was obtained applying to the matrix of data, the chord distance index (Lagonegro & Feoli, 1985).

The separation at the quite low level of resemblance (4, 7) between a couple of clusters corresponding to the associations groups of *Centaureo-Campanulion* (left) and between the whole *Potentillion caulescentis* and *Cystopteridion*, is evident.

Inside the first cluster, the maximal affinity (0, 3) is between the *Asplenio-Moehringietum* and the *Saturejo-Euphorbietum* to which the *Campanulo-Centaureetum kartschianae* and the *Campanulo-Centaureetum dalmaticae* successively bind.

This situation expresses with sufficient clarity the terms of passage from the vegetation of the sub-mediterranean coast-line cliffs, depicted by *Campanulo-Centaureetum dalmaticae* and by *Campanulo-Centaureetum kartschianae*, to the coastal chasmophytic vegetation far from the direct influence of the sea expressed by *Saturejo-Euphorbietum wulfenii* and by *Asplenio-Moehringietum tommasinii*. It appears that the latter holds a stronger transition role between the coenoses of the coast-line cliffs and the floristically ill-defined group with *Campanula pyramidalis* and *Silene saxifraga*, which, according to Poldini (1978) substitutes, in the coastal strip, the *Phyteumato-Potentilletum caulescentis* of the mountains. One can deduce it, for example, from the fact that the *Asplenio-Moehringietum*, as the two coastal communities, maintains several endemic and mediterranean elements, which are less frequent in the *Saturejo-Euphorbietum*; meanwhile, the former hosts

two oromediterranean entities: *Silene saxifraga* and *Daphne alpina* which are most frequent in the *Potentillion caulescentis*.

A plausible interpretation could be found in the geographical position of transition occupied by Trieste's Karst and by the frequency of rocky biotopes that characterize it; they are responsible for the high coenotic heterogeneity of the local chasmophytic vegetation, characterized by elements belonging to different vegetation classes (Poldini, 1989).

In the case in point, the stations of *Asplenio-Moehringietum*, even if situated at the same altitude and in the same exposure of those of *Saturejo-Euphorbietum*, benefit from a more internal and more Southerly position; the combination of these factors would consent, on one hand, the presence of thermophytic steno-mediterranean elements such as *Teucrium flavum*, and *Oryzopsis miliacea* (rel. 8), on the other, the entry of the mountane-mediterranean species.

Appendix I. Sporadic species

Relevé 1: *Chondrilla juncea* L. (+), *Lathyrus sphaericus* Retz. (+), *Parietaria officinalis* L. (+), *Pinus nigra* Arnold (+°);

relevé 2: *Erophila verna* (L.) Chevall. (2), *Silene vulgaris* (Moench) Garcke (+), *Sanguisorba minor* Scop. (+);

relevé 4: *Amelanchier ovalis* Med. (+), *Genista sericea* Wulf. (+);

relevé 5: *Frangula rupestris* (Scop.) Schur (+);

relevé 6: *Poa bulbosa* (L.) (+);

relevé 8: *Oryzopsis miliacea* (L.) Asch. & Schweinf. (+).

Appendix II. Location of relevés

1. Jugoslavia: Vena mountains, cliffs over the habitat of S. Sergio/Černikal.
2. Trieste's Karst: Val Rosandra, right slope of the canal at NE of mount Karst;
3. Same location as relevé 1;
4. Same location as relevé 2;
5. Jugoslavia: Vena mountains, overhanging cliffs under Vrh Stene (Popechio/Podpeč);
6. Same location as relevé 5;
7. Jugoslavia: Ospos's valley, Ospos's cavern, over the habitat with the same name;
8. Same location of relevé 7;
9. Same location or relevé 7;

Appendix III. Lithological remarks (edited) by F. Cucchi

Vena mountains.

The lithotypes are limestones that are part of "Membro di Opicina", a formation also known as "Calcare ad Alveoline e Nummuliti".

These are extremely pure limestones of the lower Eocene (91% calcite, 2.5% dolomite, 6.4% insoluble residues) with a calcitic sparitic matrix (the crystals are greater than 10 micron), full of organic remains, whole or fragmented, of various Foraminiferae (Alveoline, Nummuliti, Assilinae, etc.).

The rock is particularly compact often with indistinct stratification, the fracturation rate varies from a decimeter to a meter.

In Val Rosandra the lithotype is particularly compact and uniform, the stratification has a variable strength between 4 to 5 meters. The fracturation has a metric rate.

Mountains of S. Stefano (Istarske Toplice).

The lithotype is given by limestones of upper Cretaceous, generally compact, very pure (91% calcite, 2.5% dolomite, 6.4% insoluble residues), constituted by microcrystalline calcite (micrite) more or less full of minute organic residues (from 1 to 2 centimeters to a millimeter) deriving from the fragmentation of cliff organisms (Rudiste). Sometimes, even here, the stratification has a metric rate with strong banks.

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(1) Even in the commemorative speech for the disappearance of Tommasini, occurred in 1879, Marchesetti (1880b), then thirty years old, wanted to express the profound affective bonds he felt for his teacher, feelings which remained unaltered in time during his older years (cfr. Marchesetti, 1896-'97).

(2) The scientific nomenclature follows Ehrendorfer & Coll. (1973).

(3) *Sesleria juncifolia* Suffr. fo. *interrupta* Vis. is distinguished from the type by the culm with thicker base, slim and flabby leaves and lax inflorescence with few distanced spikes.

Described by Visiani (1842) as a good species and reported by Marchesetti (1896-'97) as a subspecies, it would be, according to V. Strgar (ex verbis) an ecotype of cliffs, without systematic relevance; nevertheless, because it's typical of mediterranean limestone rocks of Eastern Adriatic (Iliria) we're maintaining it in its ecological and phytosociological meaning.

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STRUCTURAL AND ECOLOGICAL VARIATION OF THE PONTIC PHYTOGEOGRAPHICAL ELEMENT FROM THE COASTAL KARST TO THE SOUTHWESTERN ALPS

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Keywords: Pontic element, Phytogeography, north-eastern Italy.

Abstract: This paper discusses the geographic trends in the distribution of the Pontic phytogeographical element (including Pontic-Mediterranean species) from the northern Adriatic coasts (Trieste Karst region) to the south-east Alps and pre-Alps.

The number of Pontic species decreases slightly from the Karst towards the pre-Alps, with a sensible reduction from the pre-Alps towards the centre of the Alpine chain. This pattern can be related to temperature. The geographic variation of life forms shows a simplification of the life form spectrum: the geophytes, being less dependent on environmental conditions, are the life form with the lowest geographic variation.

Introduction

The data bank for the floristic cartography of Friuli-Venezia-Giulia (Poldini, 1982; Poldini and al., 1985; Poldini and Vidali, 1985 and 1986), based on a program by Lagonegro et al. (1982), allowed the storage of 100.000 floristic-distributional data organized into 71 basic areas delimited as in the Central-European mapping project (Ehrendorfer and Hamann, 1965).

Such an amount of information and its automatic elaboration allow to develop new approaches for the causal analysis of floristic complexity, of which this study constitutes a first step. The purpose of the work is to study the geographic variation of the pontic phytogeographical element from the coastal Karst to the mountain areas of Friuli. The behaviour of a phytogeographical element is the result of the behaviour of the species belonging to it, and this allows a higher level of generalization. Consequently, the program will be extended to the other phytogeographical elements of the flora of Friuli-Venezia Giulia in such a way as to consent a more objective interpretation of phytogeographical phenomena and to recognize

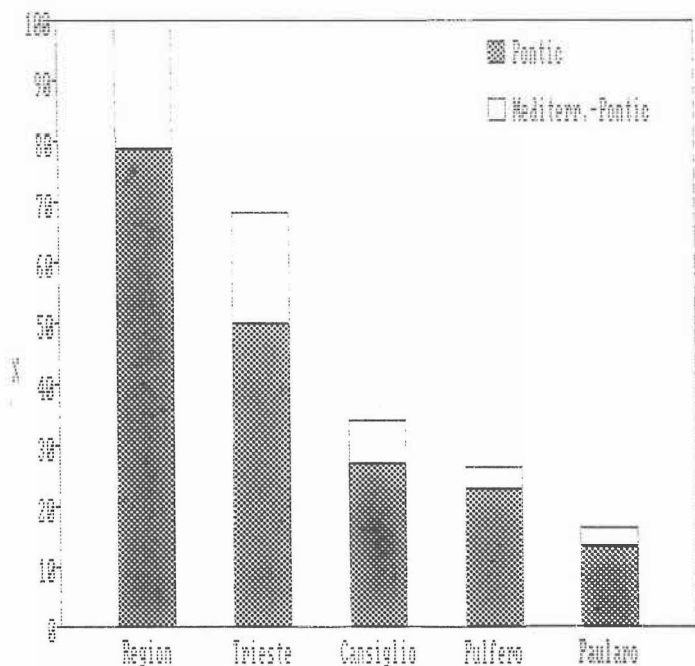


Fig. 1 — Percents of the Pontic and Pontic-Mediterranean phytogeographical elements in four basic areas, expressed on the regional total.

their main causal factors (Poldini and Vidali, 1985).

Data and Methods

For delimiting of the Pontic phytogeographical element we referred to the works of Hayek (1908, 1923), Meusel and al. (1965), Soó (1933), Walter and Straka (1970); Godicl (1980), Pignatti (1982). Even if in some cases the phytogeography of different taxa is expressed in different ways by these authors, in general they appear to be sufficiently homogeneous to avoid sensible statistical variations. Apart for some exceptions, in attributing a species to the Pontic element we took into consideration its actual distribution and not historic-genetical factors. The study area is marginal with respect to the center of origin and of diffusion of the Pontic species, located to the North of the Black Sea, and therefore only few of them are present here (see discussion and appendix).

Four basic areas, conveniently located in the regional territory, whose florulae have been exhaustively surveyed, have been selected for the analysis. They are (fig. 3):

- a) Trieste (0248) with 960 entities, situated at the south-eastern border of Friuli-

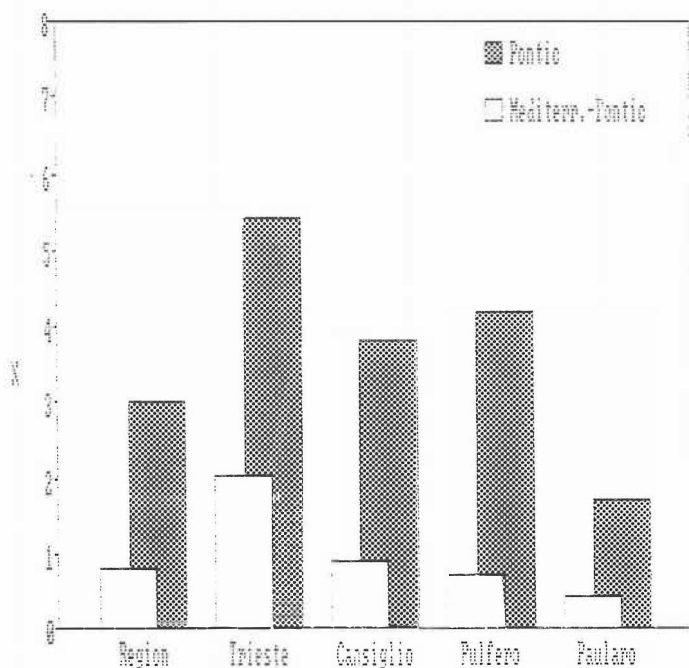


Fig. 2 — Percents of the Pontic and Pontic-Mediterranean phytogeographical elements in the regional Flora and in the florulae of the four basic areas.

Venezia-Giulia;

b) Pulfero (9846) with 576 entities on the Julian pre-Alps, at equal distance from Trieste and from:

c) Paularo (9444) with 826 entities, located on the Carnic Alps at the northern border of Friuli;

d) Cansiglio (9940) with 742 entities, situated on the Carnic Pre-Alps at the western extremity of the region.

Of these, one is located on the coast (Trieste), two in the Esalpic territory (Julian Pre-Alps: Pulfero; Carnic Pre-Alps: Cansiglio) and the last one in the Endalpic territory (Paularo). The following abbreviations will be used: T (Trieste), Pu (Pulfero), C (Cansiglio), Pa (Paularo).

The Pontic species of these basic areas have been subdivided into two groups: the Pontic group s. str. and the Pontic-Mediterranean group (see appendix). The percent variation of each of the two groups in respect with the respective florulae and with the total regional flora were analyzed.

An analogous procedure was followed for the life forms and the environment types.

Results and Discussion

Phytogeographical Elements

The Flora of Friuli-Venezia-Giulia includes 82 Pontic and 22 Pontic-Mediterranean entities which constitute respectively 3% and 0,8% of the regional Flora.

With respect to the total of 104 entities (100%), the percent of Pontic species decreases from the coast to the interior (fig. 1); on the coast (T), Pontic species s.lat. are 68,3% (50% of Pontic s.str. and 18,3% of Pontic-Mediterranean species) while in Endalpic territory (Pa) the percentage decreases to 16,3% (13,5% and 2,8%).

However, in each area the contribution of the phytogeographical elements varies significantly with respect to the regional average (fig. 2): only in the Endalpic sector (Pa), the percentages are clearly inferior (1,7% and 0,4%), whereas in the remaining areas they are greater at least for the Pontic element s.str. On the coast (T), the two groups reach together 7,4% of the relative florulae (5,4%, 2%) while even if decreasing, they still represent 4,9% (4,2%, 0,7%) and 4,7% (3,8%, 0,9%) in the eastern (Pu) and western Pre-Alpine zones respectively.

Therefore, there is a progressive decrease of the Pontic element s.str. from the coastal area (T) (the most southern) and the northern (Pa) and western (C) areas (fig. 3). This decrease is less noticeable in the pre-Alpine strip, where the percentage of the two phytogeographical elements doesn't vary in the direction East-West (Pu-C) and is always higher than the regional average.

However, different behaviours in each chorological group may be detected: the Pontic element s.str. is most frequent in the eastern pre-Alps (Pu) than in the western ones (C), while the opposite occurs with the Pontic-Mediterranean element. The latter being represented by more thermophytic entities, it suffers from the weaker Mediterranean climatic characters of the eastern sector (Pu) compared to the western one (C). In fact, in Cividale's valleys (Pu) there are about twelve months of rain against the six months of the Tramontino (C) with a mean precipitation of 2100 mm/year (Gentilli, 1964) against about 1800 mm/year (Polli, 1972). In the case of the Pontic element s.str., less sensitive to the macro-climate, the opposite situation is justified with the greater distance from the center of origin.

The pronounced sensitivity of the Pontic-Mediterranean element regarding the climate, finds further confirmation in the fact that in the passage from the coast (T) to the Endalpic area (Pa) this element is reduced by about five times with respect to the three times of the other element: the coast (T) possesses 19 out of the 22 Pontic-Mediterranean taxa and 52 of the 82 Pontic ones; such values are reduced to 7/22 and 28/82 on the Western Pre-Alps (C), to 3/22 and 14/82 in the Endalpic zone (Pa).

Life Forms

The most evident result which emerges from the analysis of life forms, within the

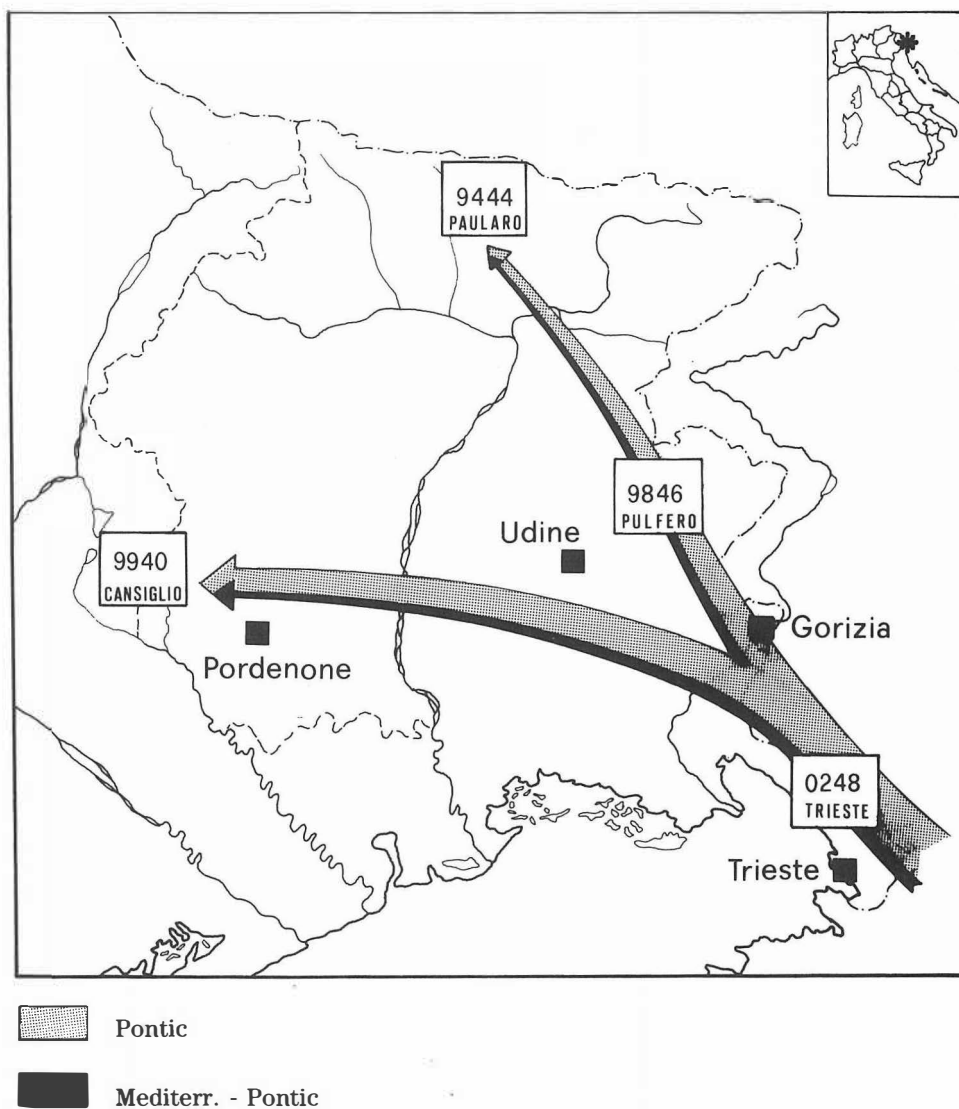


Fig. 3 — Localization of the four basic areas, and variation of the two phytogeographical elements from coastal Karst to south-eastern Alps.

phytogeographical elements in question, is the simplification of the life form spectrum proceeding towards the North. This is much more noticeable for the Pontic-Mediterranean element (fig. 4) which hosts only phanerophytes and hemicryptophytes on the eastern pre-Alps (Pu) and in the interior Alpine territory (Pa).

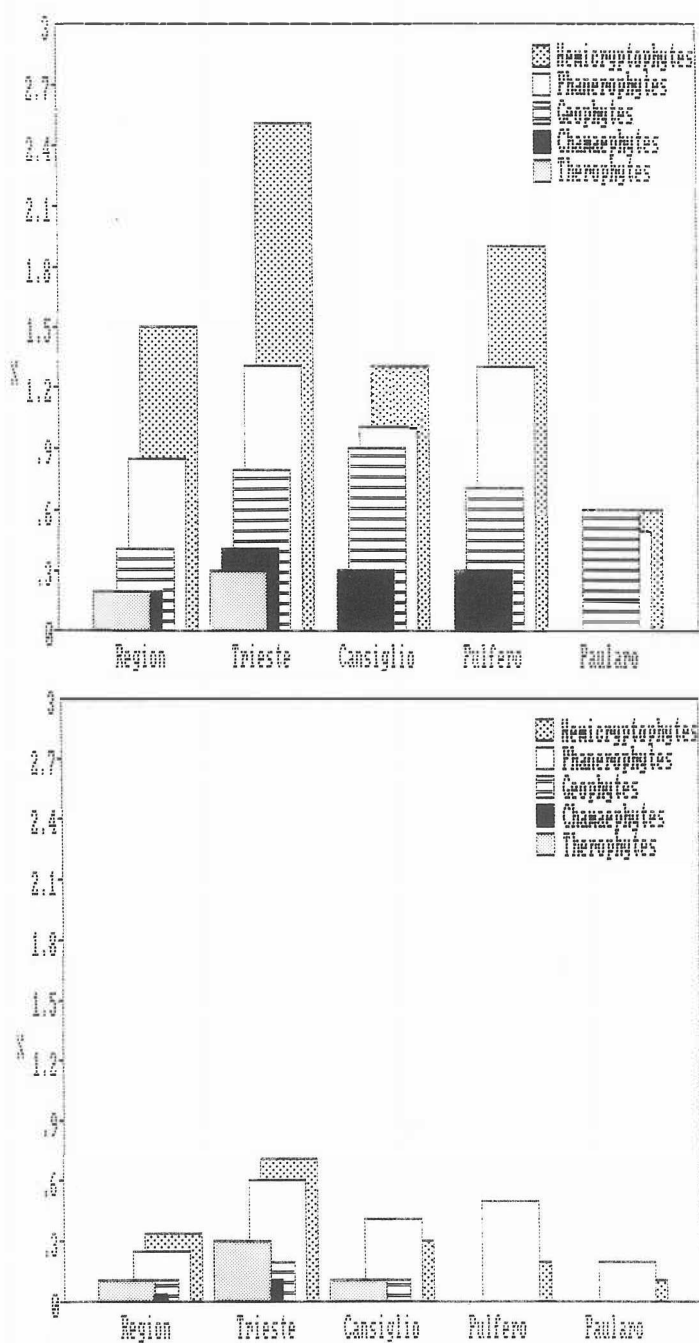


Fig. 4 — Life-form spectrum of the Pontic and Pontic-Mediterranean phytogeographical elements in the regional Flora and in the florulae of the basic areas.

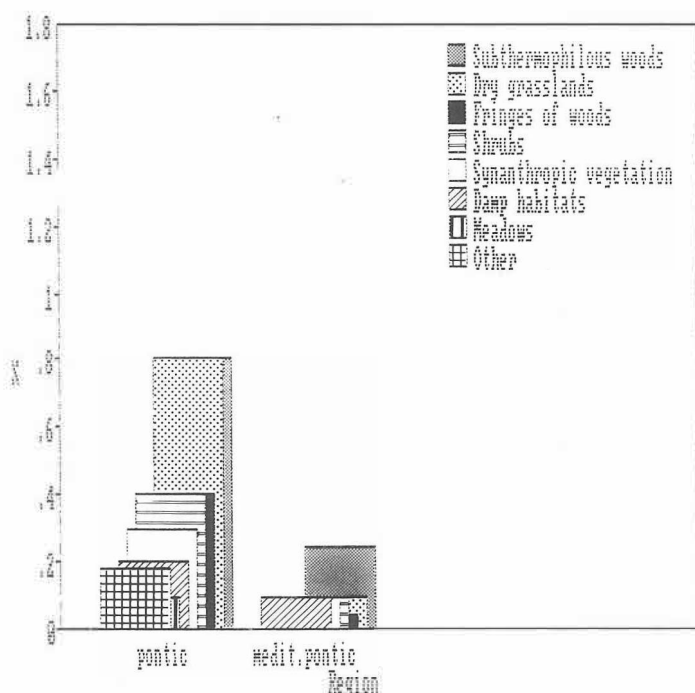


Fig. 5 — Biotopical spectrum of the Pontic and Pontic-Mediterranean phytogeographical elements in the Flora of Friuli-Venezia Giulia.

The Pontic element s.str. is represented by more life forms, because, as seen, it suffers less drastically from the climatic change. This involves a more gradual decrease of some components and a less pronounced simplification of the spectrum in its whole.

In both cases, therophytes appear to be the most sensitive; on the coast (T) they always have values above the regional average, which rapidly decrease inwards, being this element the most tied to the Mediterranean climate.

Interesting is the relative constance of the Pontic geophytes, probably due to their greater independence from the climatic and seasonal variation, especially with respect to the time of anthesis. This relative stability of the geophytes appears even more evident when we compare it, for example, to the variation of the hemicryptophytes (or of the chamephytes) which on the coast (T) are about 3 times more numerous than the geophytes, while in the interior (Pa) they have the same consistency.

Environmental types

The comparison between biotopical spectra (fig. 6) reveals that the Pontic

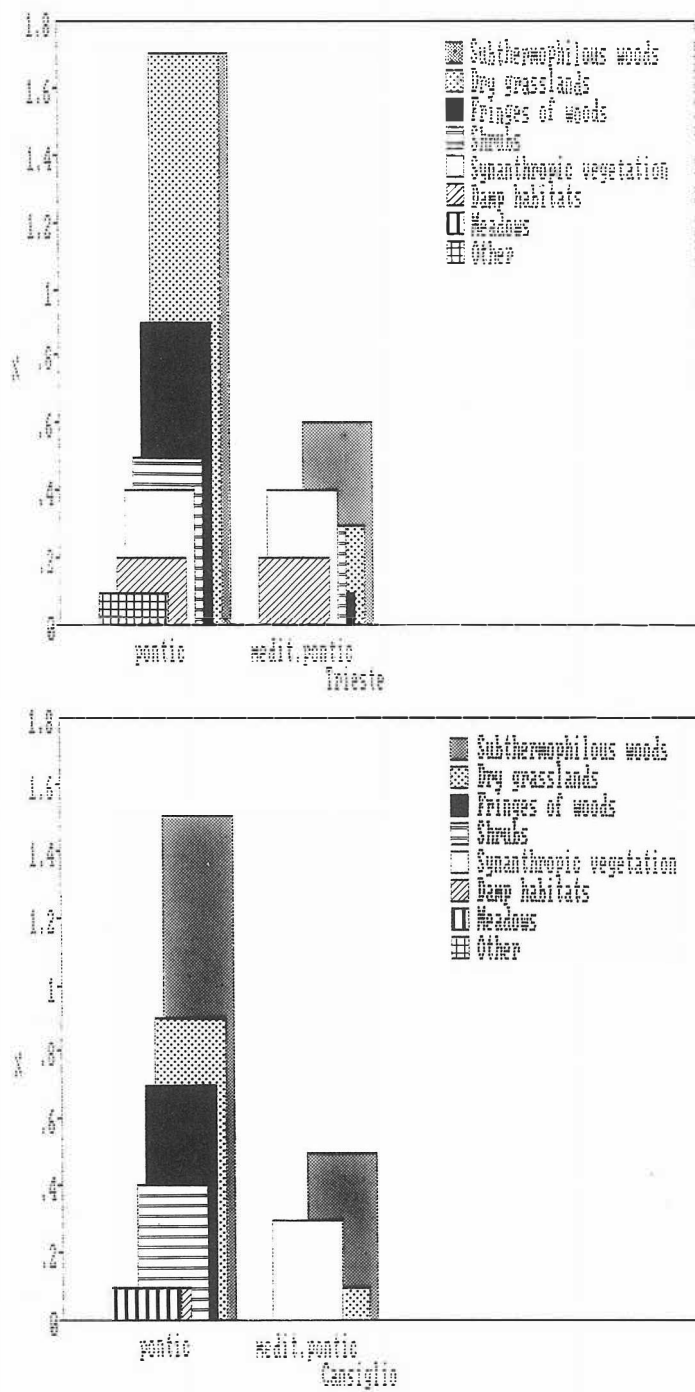
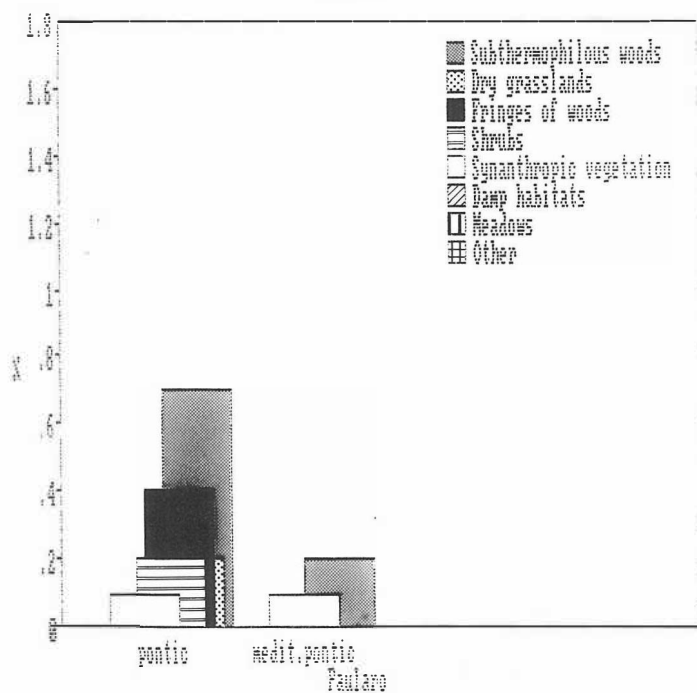
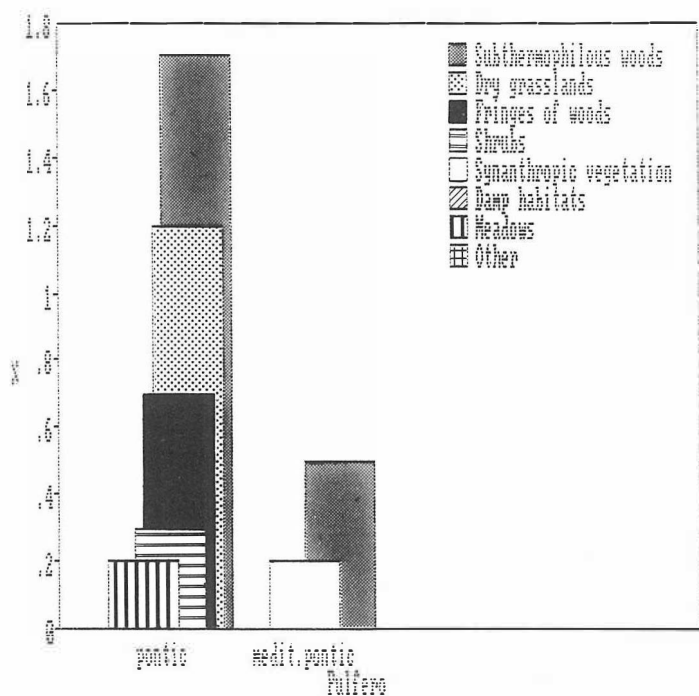


Fig. 6 — Variation of the biotopical spectra of the Pontic and Pontic-Mediterranean phytogeographical elements among the basic areas.



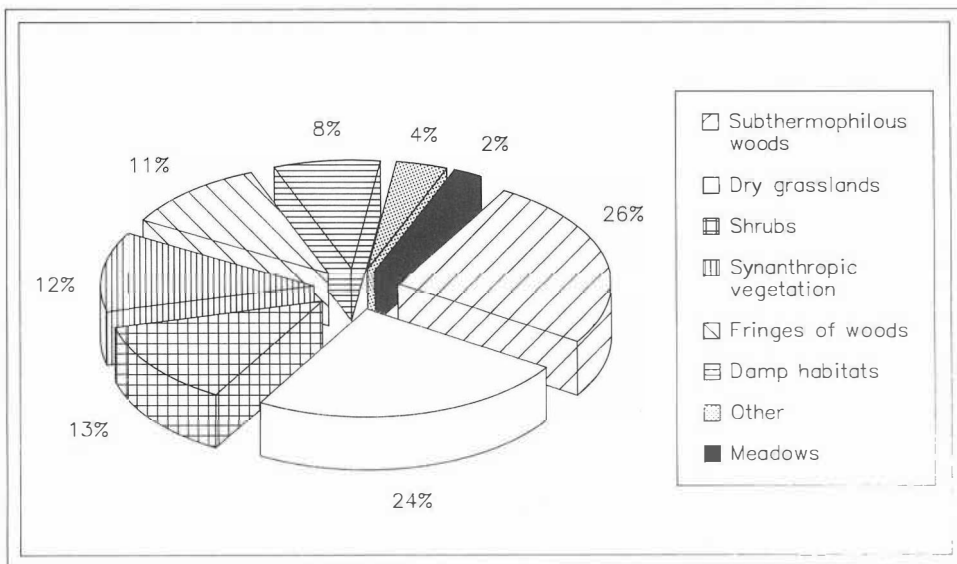


Fig. 7 — Biotopical spectrum of the Pontic element s.lat. (Pontic s.str. + Pontic-Mediterranean) in Friuli-Venezia-Giulia.

element s.str., with respect to the Pontic-Mediterranean, occupies a broader ecological spectrum.

Assuming as a reference the biotopical spectrum of the region (fig. 5) we observe that the species of rich meadows are absent in the coastal area (T). Rich meadows are not common in the territory and mostly are dominated by species of the Eurosiberian and Central-European elements. Poldini and Vidali (1987) studying the presence of the Pontic element s.lat. within seven herbaceous coenoses of Trieste's Karst, demonstrate an impoverishment of the biotopical spectrum of the Pontic element in the synanthropic vegetation and in humid environments.

The behaviour of the Pontic-Mediterranean element is rather different. A drastic simplification of the spectrum can be observed, which is reduced to three components on the Western Pre-Alps (C) and to only two on the Eastern Alpine area (Pu, Pa). Differently from the Pontic entities, the group of species tied to the synanthropic vegetation persists in all the basic areas, presumably because the disturbed surroundings, with their primitive pedologic situation and the meagre vegetation cover, create favourable conditions for these plants. Probably, the Pontic-Mediterranean element is the most prone to apophytism, and contributes to the colonization of the devastated biotopes since these are more arid than the natural ones.

The biotopes with higher incidence of the Pontic element s.l. are (Fig. 7): subthermophytic woods (26%) and dry pastures and slopes, which host half of the species; also relevant is the contribution of the scrub vegetation (13%), of the

synantropic vegetation (12%), and of the margins of the woods (11%).

Conclusions

The results confirm the high sensitivity of a phytogeographical element at the margin of its distribution with respect to climatic variations. The climate operates a gradual reduction of species, positively selecting those with a more euryecious character (the Pontic s.str. with respect to the Pontic-Mediterranean). This is reflected on the structure of the life form and biotopical spectra, which are progressively impoverished.

The simplification of the life form spectrum shows the selection of more competitive life forms, as the geophytes, less influenced by environmental factors.

The extreme simplification of the biotopical spectrum of the Pontic-Mediterranean element is due to the shelter-like character of the stations in which it is present inside the Alpine territory, where it is mostly restricted to thermophytic coenoses and has to evade the competition (oligotrophic stations).

Riassunto

Il lavoro tratta il comportamento del geoelemento pontico s.l. (includente le specie mediterraneo-pontiche) dalla costa Adriatica settentrionale (Carso triestino) alle Prealpi e Alpi sudorientali. È stato osservato che la riduzione del numero delle specie pontiche che si riscontra lungo le Prealpi (E-W) è minore di quella che si può osservare procedendo alla costa verso la catena alpina (SE-NW). Questa variazione è in relazione con la temperatura.

Lo studio delle forme biologiche rivela una semplificazione dello spettro biologico. Le geofite, non dipendenti dalle condizioni ambientali, sono le forme biologiche che manifestano la variazione più contenuta.

Appendix

Note: for each species, the life - and growth - forms are expressed according to Raunkiaer's system; the abbreviations of the principal environment-types are as follows: B: humid environments; C: rich meadows; D: subthermophytic woods; F: dry pastures and slopes; I: margins of woods; M: synantropic vegetation; N: bogs; P: scrub vegetation; Q: cultivated and naturalized species; Y: mountain pastures.

In the histograms, the biotypes N, Q, Y, due to their scarce representation, were incorporated under the voice "others".

Pontic Element

Abutilon theophrasti Med., T scap, M; *Aegilops cylindrica* Host, T scap, M; *Althaea cannabina* L., H scap, M; *Alyssum montanum* L., Ch suffr, M; *Anthemis tinctoria* L., Ch suffr, M; *Anthyllis vulneraria* L. ssp. *polyphylla* (DC.) Nyman, H scap, F; *Asparagus tenuifolius* Lam., G rhiz, D; *Astragalus cicer* L., H scap, I; *Atriplex oblongifolia* W. et K., T scap, M; *Buglossoides purpureocaerulea* (L.) I.M. Johnst., H scap, D;

Bupleurum praealtum L., T scap, I; *Carex michelii* Host, H caesp, F; *Carpesium cernuum* L.; T scap, I; *Carpinus orientalis* Mill. P caesp, D; *Cercis siliquastrum* L., P scap, Q; *Cirsium canum* (L.) All., G rhiz, B; *Cirsium pannonicum* (L.f.) Lk., H scap, C; *Cornus mas* L., P caesp, D; *Coronilla coronata* L., Ch suffr, I; *Cotoneaster integerrimus* Med., NP, D; *Cotoneaster tomentosus* Lindl., NP, P; *Crambe tataria* Sebeok, H scap, F; *Dentaria bulbifera* L., G rhiz, D; *Digitalis grandiflora* Mill., H scap, D; *Dorycnium germanicum* (Gremli) Rikli, H scap, F; *Dorycnium herbaceum* Vill., H scap, F; *Echinops ritro* L. ssp. *ruthenicus* (Bieb.) Nyman, H scap, F; *Euonymus verrucosus* Scop., P caesp, D; *Ferulago galbanifera* (Mill.) Koch, H scap, I; *Fraxinus angustifolia* Vahl, P scap, B; *Galega officinalis* L., H scap, B; *Gentianella austriaca* (A. et J. Kern.) Holub, H bienn, Y; *Geranium pratense* L., H scap, C; *Hesperis candida* Kit. ex Hayek, H scap, D; *Inula ensifolia* L., H scap, F; *Iris graminea* L., G rhiz, I; *Iris sibirica* L., G rhiz, B; *Lactuca quercina* L., H bienn, I; *Lathyrus venetus* (Mill.) Wohlf., G. rhiz, D; *Lembotropis nigricans* (L.) Griseb., NP, P; *Linum flavum* L., H scap, F; *Linum tenuifolium* L., Ch suffr, F; *Lonicera caprifolium* L., P lian, D; *Medicago prostrata* Jacq., H scap, F; *Melica picta* Koch, H caesp, P; *Mercurialis ovata* (Sternb.) Hoppe, G rhiz, D; *Mercurialis x paxii* Graebner, G rhiz, D; *Mespilus germanica* L., P caesp, D; *Ornithogalum refractum* Kit., G bulb, M; *Paliurus spina-christi* Mill., P caesp, P; *Plantago argentea* Chaix, H ros, F; *Plantago holosteum* Scop., H ros, F; *Potentilla alba* L., H ros, D; *Potentilla arenaria* Borkh., H scap, F; *Potentilla cinerea* Chaix, H scap, F; *Potentilla tommasiniana* F.W. Schultz (1), H scap, F; *Prunus avium* L., P scap, D; *Prunus cerasifera* Ehrh., P caesp, P; *Prunus mahaleb* L., P caesp, P; *Pulsatilla montana* (Hoppe) Rchb., H scap, F; *Quercus pubescens* Willd., P caesp, D; *Ranunculus illyricus* L., H scap, I; *Rhamnus cahtarticus* L., P caesp, P; *Rhamnus saxatilis* Jacq., P caesp, F; *Rosa corymbifera* Borkh., NP, P; *Rosa gallica* L., NP, N; *Rosa tomentosa* Sm., NP, P; *Rosa villosa* L., NP, P; *Ruta graveolens* L., Ch suffr, F; *Scorzonera austriaca* Willd., H ros, F; *Scorzonera aristata* Ramond ex DC., H ros, Y; *Sedum hispanicum* L., T scap, M; *Seseli annuum* L., H bienn, F; *Seseli carvifolium* Vill., H bienn, D; *Seseli libanotis* (L.) Koch, H scap, I; *Staphylea pinnata* L., P caesp, D; *Succisella inflexa* (Kluk) Beck, H scap, B; *Symphytum tuberosum* L. (incl. *S. nodosum* Schur.), G rhiz, D; *Thesium bavarum* Schrank, G rad, I; *Tragopogon dubius* Scop., H bienn, M; *Trifolium montanum* L., H scap, F; *Vicia grandiflora* Scop., H scap, I.

Pontic-Mediterranean Element

Bothriochloa ischaemon (L.), Keng., H caesp, F; *Cerastium brachypetalum* Desp. et Pers., T scap, M; *Cerastium glutinosum* Fries, T scap, M; *Colutea arborescens* L., P caesp, O; *Coronilla emeris* L. ssp. *emeroides* (Boiss. et Sprun.) Holmboe (1), NP, D; *Cotinus coggygria* Scop., NP, P; *Euphorbia angulata* Jacq., G rhiz, D; *Fraxinus ornus* L., P scap, D; *Fumana procumbens* (Dunal) Gren. et Godr. Ch suffr, F; *Lactuca viminea* (L.) J. et K. Presl, H bienn, M; *Lysimachia punctata* L., H scap, B; *Medicago sativa* L., H scap, M; *Oryzopsis virescens* (Trin.) Beck, H caesp, D; *Ostrya carpinifolia* Scop., P caesp, D; *Potentilla recta* L., H scap, F; *Rorippa austriaca* (Cr.) Bess., H scap, B; *Rosa micrantha* Borr. ex Sm., NP, P; *Ruscus hypoglossum* L., G rhiz, D; *Tetragonolobus maritimus* (L.) Roth., H scap, B; *Trifolium ochroleucum* Huds. H. caesp., F; *Viburnum lantana* L., P caesp, D; *Vicia villosa* Roth ssp. *varia* (Host) Corb., T scap, P.

(1) Note

Because of the low degree of differentiation with respect to the species of origin, entities like this one, strictly speaking an endemic one, have been considered as Pontic or Pontic-Mediterranean elements.

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ANTHESIS AND POLLINATION OF SOME TREES IN THE SURROUNDINGS OF TRIESTE

L. RIZZI LONGO

Keywords: Aerobiology, Palynology, Phenology, Trieste.

Abstract. The transported and deposited pollen curves of 12 tree taxa in the outskirts of Trieste are reported. Meteorological data, the frequency of the taxa in the survey area, and phenologic observations on the anthesis periods have been used for the interpretation of the pollen curves.

There is a generally good correspondence between pollination and deposition peaks, and the anthesis periods. The pollination curves allow to distinguish the contributions of sources at different distances from the trap. There are some correlations between meteorological factors and quantitative variation of airborne pollen.

Introduction

The study of the airborne biological material provides information for various purposes. Many aerobiological researches examine the airborne allergenic pollen content and compile pollen calendars for the diagnosis and prevention of pollinosis. Other studies aim at the acquisition of more general data, to clarify the ways of dispersion and of transport of the pollen in the atmosphere (Subba Reddi and Reddi, 1985; Mandrioli et al., 1980), also in relation to: meteorological factors (Mandrioli, 1987; Mercuri et al., 1982; Andersen, 1974; Liem and Grot, 1973), the relation between pollen production, anthesis and atmospheric content (Zerboni et al., 1988) and pollen deposition (Benninghoff, 1987), the relations between vegetation, aerobiological content (Zerboni et al., 1987; Hibino, 1976) and the recent and fossil pollinic spectra (Heim, 1970; Montanari, 1986; Birks, 1980).

In this study, the airborne pollen content of some tree taxa, and the pollen deposition in a peripheral zone of Trieste are analyzed; the results are interpreted on the basis of phenological and meteorological data. The pollen content of the urban atmosphere of Trieste has been already studied, so that the pollination curves of the main allergenic taxa and the pollen calendar are known (Rizzi Longo and Cristofolini, 1987).

Trieste is located at the eastern extremity of the Gulf of Trieste, in a zone of phytoclimatic boundary between the Mediterranean and Euro-siberian regions. The town is poor in green areas: parks and gardens are few and small, avenues are

rare. In the suburbs, on the sandstone hills, there is a small cultivated area, mostly with vineyards and orchards, followed by oak-woods. The strip of hills is rather narrow, being cut-off by the edge of the Karst Plateau (average height 250m) which constitutes an important phytoclimatic barrier (Poldini, 1971).

Materials and Methods

Twelve of the most representative natural and introduced trees were considered. During 1979, periodic observations on the phenology of trees and on the airborne and deposited pollen were carried out. The phenological observations refer exclusively to the anthesis period, using Marcello's scale (1935); they were carried out on different samples of the same species, located, when possible, near the pollen trap.

The airborne pollen has been collected through a COUR trap (1974) located on the roof of the building of the Biology Department, at 20 m from the ground on the downhill side, and at about 3 m on the uphill side (Fig. 1). The Biology Department, in the north-western outskirts of the city, is built on the southern slope of the sandstone hills surrounding the urban nucleus at an elevation of 124 m. Downhill there is the University campus followed by the urban area; uphill there are the woods of M. Fiascone (213 m). Towards the west the sampling point faces a small valley with houses and orchards, separating Monte Fiascone from the woody hill of Scorcola. For the particular location of the trap, so close to the emitting source, it is possible to obtain data on the pollen release and on its deposition.

Two COUR traps were used, one with two vertical (VFU), the other with one horizontal filtering units (HFU). The VFUs, made of 5 hydrophylic gauze layers (mesh 10/7) soaked in silicone oil (viscosity 1000 csk) and in turpentine oil, are vertically placed within 2 squares of 20 cm, and always kept against the wind by means of a calibrated rudder. The HFU, made of 8 hydrophylic gauze layers treated as the former ones, is fixed within squares of 20 cm, placed horizontally, and collects the deposited material. The filtering units are changed every week.

The trapped pollen is freed, according to the methodology of Cour (1974), by a series of chemical treatments of the filtering units, which allow: the destruction of the hydrophylic gauze (70% HF), the elimination of other inorganic components (20% HCl), the destruction of the plasmatic content (acetolysis according to Erdtman, 1969) and the coloration of the acetolyzed pollen with basic fuchsin. Through the volumetric measure of the precipitate and through an accurate preparation and lecture of the microscopic slides (Cour, 1974), data with standard procedure are obtained. From the basic data (number of pollen grains in a given slide), through formulas (Cour, 1974), the number of pollen grains per square meter per day (average weekly value) is obtained. The quantity of pollen intercepted by the HFU is much lower than the one intercepted by the VFU; consequently different scales are used for the graphic representation.

The meteorological data have been taken from the 1979 records of the Istituto Talassografico di Trieste. They are summarized in fig. 3.

The nomenclature is from Poldini (1980). The chorological and phytosociologi-

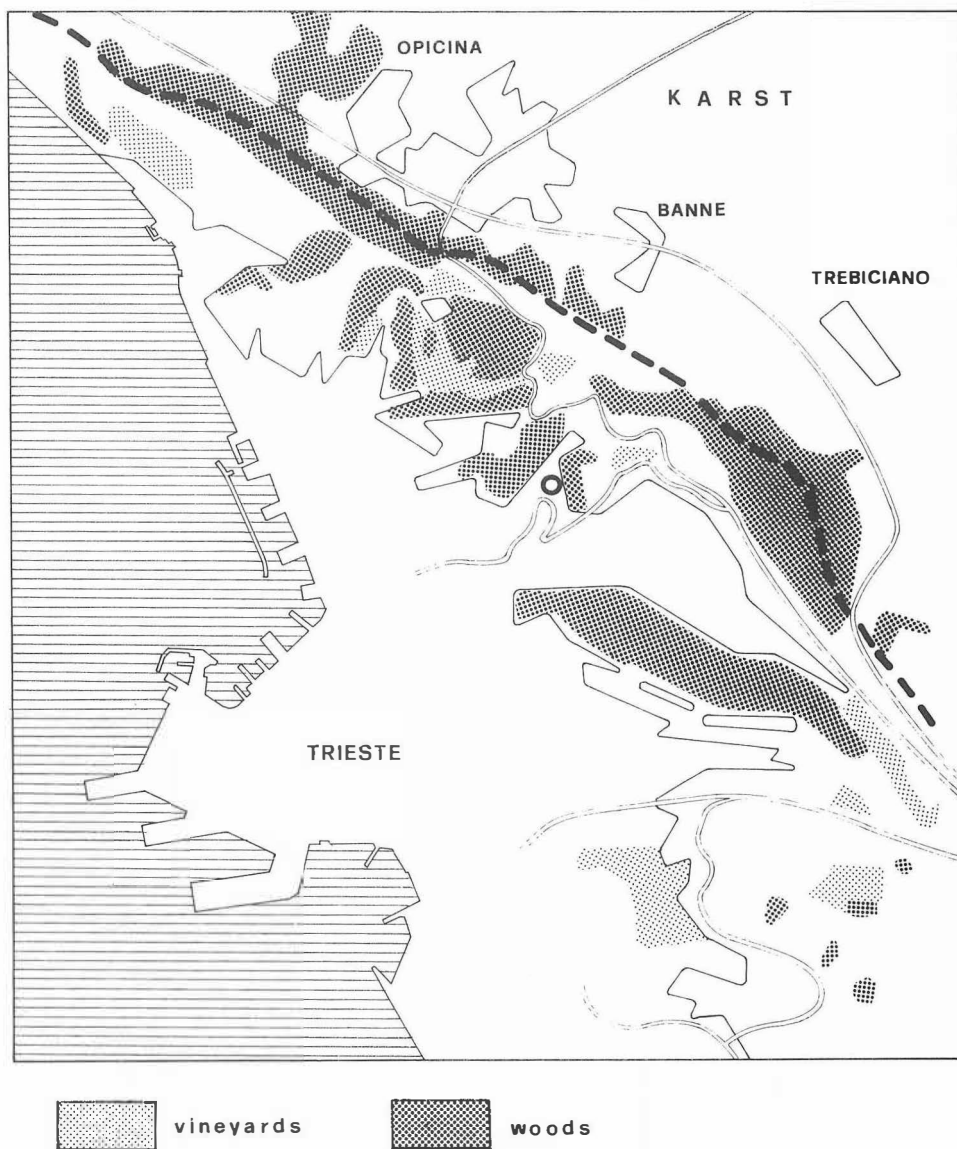
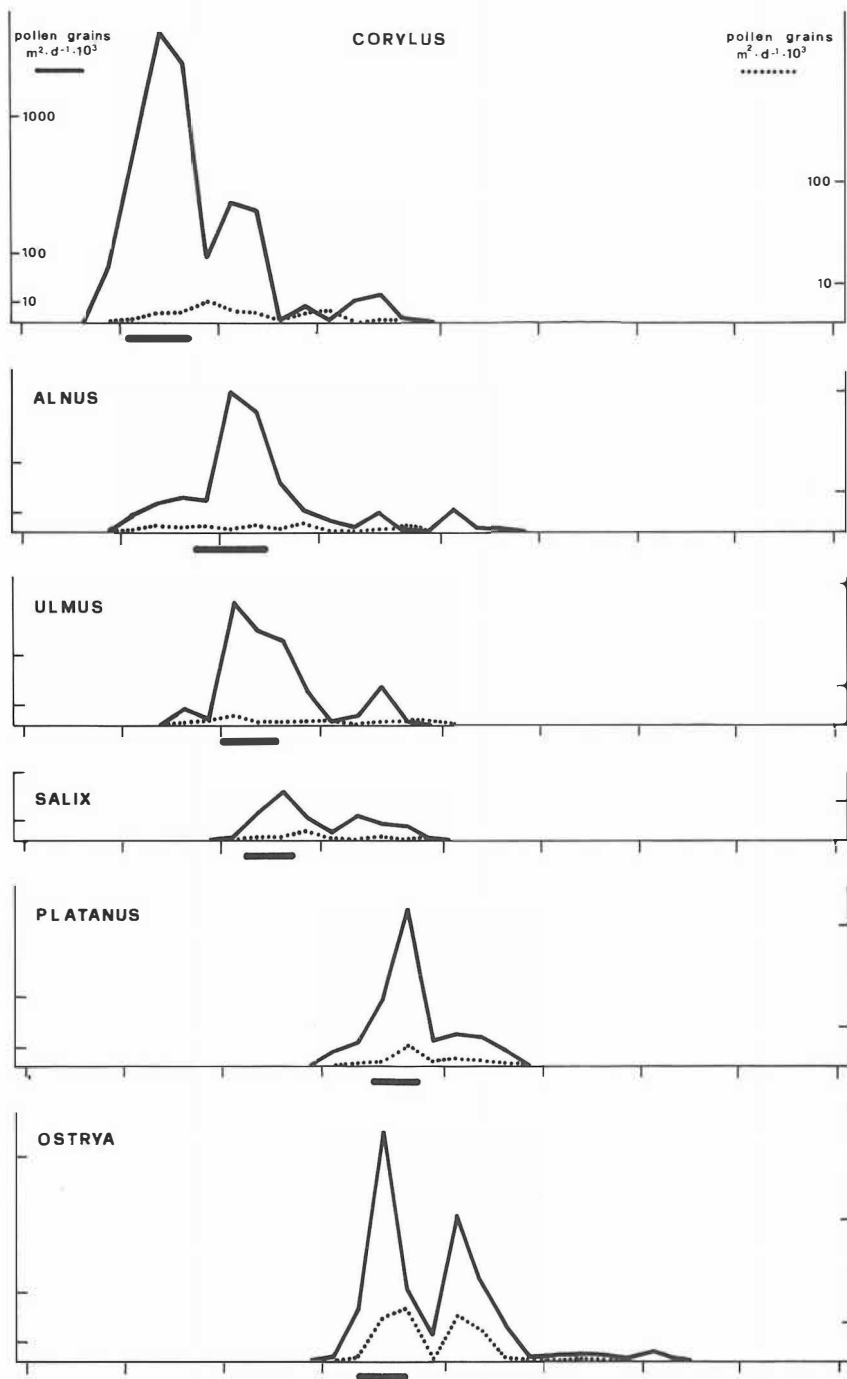


Fig. 1 — Location of the pollen trap (o) within the town of Trieste (after Poldini, 1977, modified).

cal data are from Oberdorfer (1979), Pignatti (1982), and Poldini (1988).

Results

The pollen curves and the anthesis periods of the 12 tree taxa are shown in Fig.



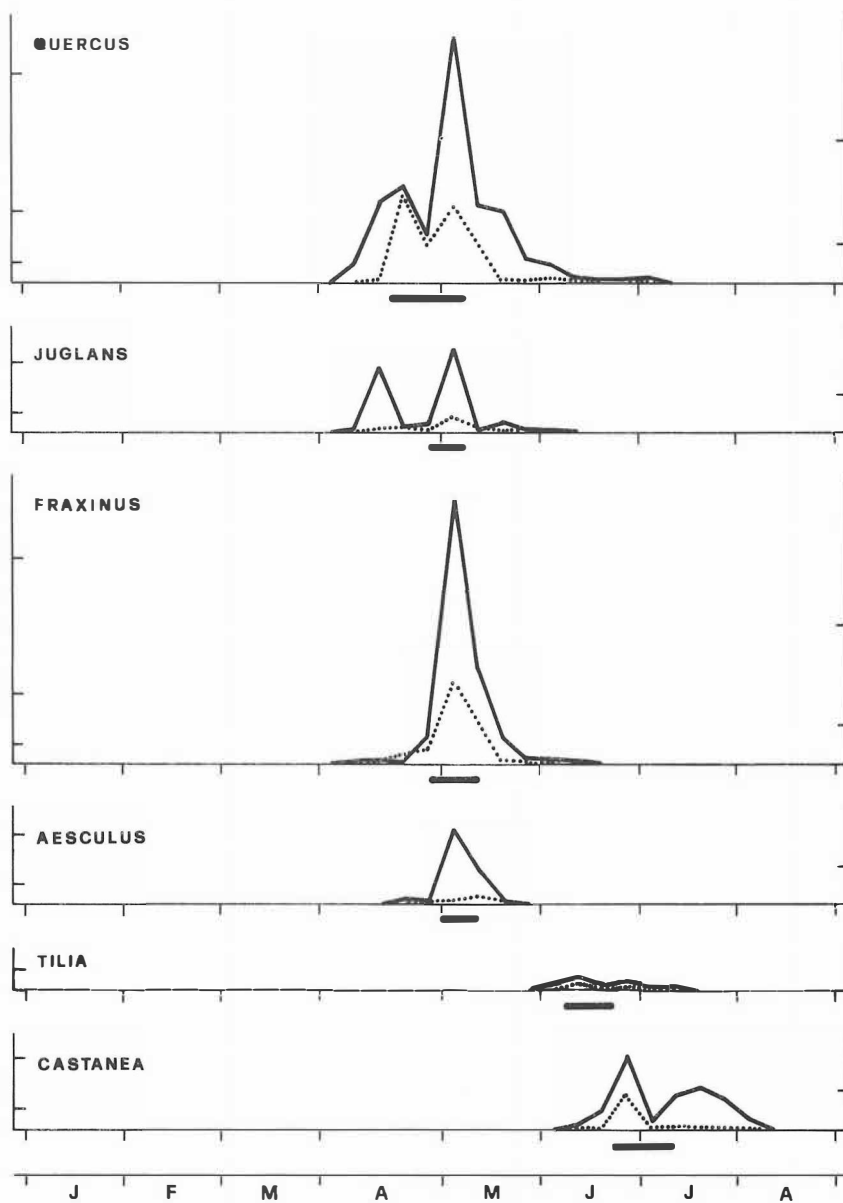


Fig. 2 — Pollination curves of different tree taxa in the survey area. Continuous line: transported pollen; dotted line: deposited pollen. The anthesis period is shown by horizontal lines below the time scales.

2. In the following, each taxon will be briefly discussed.

Corylus L.

In the region the following species occur, *C. avellana* L. and *C. maxima* Mill. The latter is cultivated.

C. avellana is a subatlantic element, characteristic of the *Quercus-Fagetum* vegetation class; in the South of the Alps, it is associated with the *Carpinion* alliance (Poldini, 1988). It is a species of forest edge, of underwoods, growing in the Karstic dolines, and in shrub thickets. Near the trap, there are a few individuals of *C. avellana*.

The pollination peak, around mid-February, fully corresponds to the anthesis period. A second peak, in the first half of March, is due to the blooming of the Karst populations; the increase of atmospheric pollen around mid-April could be due to the blooming of the populations in the interior Karst mountains. The presence of *Corylus* pollen before the anthesis is due to individuals of lower, more protected and sunny sites, with early blooming. The pollen of *Corylus* is easily transported (Gambarelli et al., 1985, give a free fall value of 5,51 cm/sec) and remains for a long time in the atmosphere; the shrubs next to the trap have a limited pollen production so that the HFU values are low.

Alnus Mill.

In the Trieste region there is only *A. glutinosa* (L.) Gaertn., a suboceanic-submediterranean Eurasiatic species, frequent in the riparian woods and in the *Alno-Ulmion* communities. It is not frequent in the area, because of the scarcity of rivers.

The pollination peak, around mid-February, is delayed with respect to the beginning of the anthesis. This is related with the distance of the emitting sources, located at the extreme east of the city (Val Rosandra). The other peaks are due to specimens of montane alders (*A. incana* (L.) Moench and *A. viridis* (Chaix) DC.) of the interior Karst (mid-April) and of the Julian Alps (beginning of May).

Also the pollen deposition is rather scarce and the pollination curve remains low and uniform. A higher pollen deposition occurs at the end of March, as an effect of rain.

Ulmus L.

Only *U. minor* Mill. is present in the area. It is a submediterranean element, growing in humid woods and shrublands, at the edges of *Quercus pubescens* woods, along peripheral roads, between houses in sunny stations, and in disturbed areas.

The pollination peak at the beginning of March corresponds to the anthesis period close to the trap; the early pollen appearance, and its persistence after the end of the anthesis period, are related, the former with the early blooming of

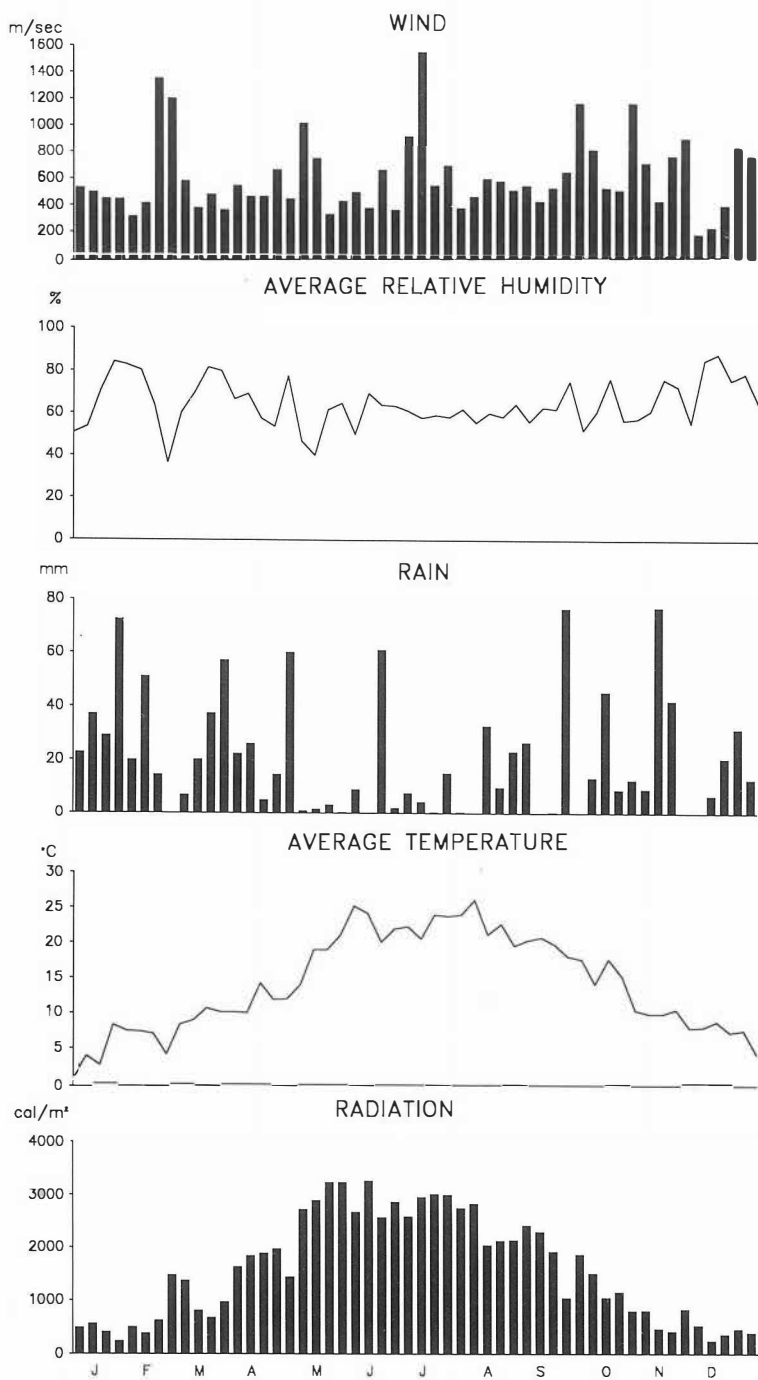


Fig. 3 — Weekly trends of weather conditions in the survey area.

individuals of lower zones (town center), the latter to the delayed blooming of individuals at higher altitudes (Karst). The further increase at mid-April is due to the blooming in the interior Karst.

There are no elms in the proximity of the trap; the pollen found in HFU is deposited aerotransported pollen. The HFU pollination curve is rather weak and uniform. Nevertheless, there is a correspondence between the peaks of atmospheric and of deposited pollen.

Salix L.

Willows grow in humid places, such as river shores, lakes and ponds. In the region of Trieste, they are not common, due to the scarcity of surficial waters. They occur in the eastern sector, along the short waterways of the Rosandra and Osopo Rivers, with the species *S. alba* L., *S. eleagnos* Scop., and *S. purpurea*.

Less frequent are willows of the *S. caprea* group (*S. cinerea* L., *S. caprea* L.), that grow in humid woods, in pioneer shrub thickets, and on deep and humid soils.

The pollination curve of *Salix* shows a small peak around mid-March, more or less in correspondence with the anthesis of *S. caprea* from the hill belt, and a second period of minor importance, in April, which is due to the willows of the interior Karst with delayed blooming. Willows are partially entomophilous: also considering their scarcity in the survey area the amount of airborne pollen is high.

The pollen deposition is scarce, with a peak at the end of March, corresponding to intense precipitations.

Platanus L.

In the region, only *P. x hybrida* is present; it is a cultivated tree, frequent in parks, gardens and avenues.

The pollination curve presents only one peak, corresponding to the anthesis period and to the maximum of deposited pollen. In spite of the rarity of plane-trees, its pollen is well represented, also because some trees grow near the trap.

Ostrya Scop.

Ostrya carpinifolia Scop., an eastern mediterranean element, is abundant in the survey area. It is dominant in open woodlands belonging to the *Ostrya-Carpinion orientalis* alliance, characterizing the transition between oak-woods and Karstic open woodland, and between the latter and the pine-woods (Poldini, 1982)). It is a differential species of the Mediterranean maquis, which is a relict formation along the Trieste coasts (*Ostrya-Quercetum ilicis*; Trinajstić 1975).

The pollination curve has two important peaks, the first at mid-April, of 1.264.116 pollen grains m^{-2}/d , corresponding to the blooming of populations of the same altitudinal belt at the trap, and a second one, at the beginning of May, of 680.022 pollen grains m^{-2}/d , due to the anthesis in the Karst.

The pollen of *Ostrya* is also abundant in the HFU, with a peak of 19.234 pollen grains m^2/d , corresponding to the peak in the VFU.

Quercus L.

Q. ilex L., a stenomediterranean element, characteristic of the *Quercetalia ilicis* order, is common along the coasts, in the Mediterranean maquis. It is also cultivated in avenues and parks, mostly along the coasts.

Q. cerris L., an eastern Mediterranean element, grows on deep, humid soils, mostly in dolines and small humid valleys.

Q. petraea (Matt.) Liebl., a subatlantic-submediterranean element, characteristic of the *Querco-Fagetea* class, forms extensive woods on sandstone slopes with acid soils that surround the town (*Seslerio-Quercetum petraeae*; Poldini, 1982). *Q. daleschampii* Ten., a very similar species, occurs in the Karst Plateau.

Q. pubescens Willd., a submediterranean element characteristic of the *Quercetalia pubescentis* order, frequently forms open woodlands on dry calcareous ground (*Ostryo-Quercetum pubescentis* Trinajstić 1974).

The pollination curve of the genus *Quercus* has several peaks. The anthesis period is generally a little out of phase in the various species: generally the earliest is *Q. petraea*, followed by *Q. pubescens* and by the late blooming by *Q. ilex*. Since *Q. petraea* and *Q. pubescens* are by far the most frequent species, the anthesis period near the trap is referred solely to them. The first pollination peak, in the second half of April, seems mostly due to the blooming of *Q. petraea*: the very high values are due to individuals growing just above the trap; this explains also the high deposition values, since a good part of tree pollen falls not far from the source (Guido, 1988). The peak of 1.429.430 pollen grains m^2/d at the beginning of May is mostly due to mass blooming of *Q. pubescens* on the Karst Plateau; this peak is also evident in the HFU, even if less pronounced because of the greater distance of *Q. pubescens* populations from the trap. In the VFU, the peak of May is followed by a tail of airborne pollen, due mainly to the delayed pollination of *Q. ilex*.

Juglans L.

Only *J. regia* L. is present in the survey area; it is an eastern Mediterranean Eurasiatic species, cultivated since antiquity and now subsponaneous, with isolated individuals in the countryside, in the outskirts of the town and in the Karst.

The pollination curve is rather discontinuous. The first VFU peak is interpreted as due to the early blooming in lower and more protected zones; the anthesis period of the trees close to the trap corresponds to the peak at the beginnings of May and to the maximum of deposited pollen in the HFU.

Fraxinus L.

F. ornus L. is widespread in the survey area, it is an eastern Mediterranean

element, characteristic of thermophylous woods of south-eastern Europe, with a very broad ecological range, from the Mediterranean belt to the thermophylous beech-woods. It's abundant both in the Karstic woodland and in the understorey of pine-woods.

The pollination peak, with 1.873.130 pollen grains m^2/d , at the beginnings of May, corresponds with the mass blooming of *F. ornus* on the Karst slopes.

The pollen deposition is high, with a maximum of 39.183 pollen grains m^2/d , corresponding to the peak in the VFU; this is probably due to emitting sources close to the trap.

Aesculus L.

Ae. hippocastanum L. is frequently cultivated in avenues and parks, and is a Balcanic element. *Ae. carnea* Hayne, a North American hybrid between *Ae. hippocastanum* and *Ae. pavia* L., is less frequent.

Notwithstanding the entomophylous impollination, the airborne pollen is frequent, with a peak at the beginnings of May, in correspondence to the anthesis period. Its presence in the HFU is scarce, in spite of the relative vicinity to the trap of many individuals, that, however, are located laterally and separated from the trap by buildings.

Tilia L.

In the urban and suburban districts, *T. tomentosa* Moench and other hybrids are frequent, and are used in avenues and parks. *T. cordata* Mill., and European-Caucasian element, characteristic of the *Tilio-Acerion* alliance, and *T. platyphyllos* Scop., are sporadic in oak woods, in Karstic villages and in the countryside.

The presence of airborne pollen is scarce, due to the impollination type and to the pollen heaviness. Proportionally to this scarceness of transported pollen, the deposition appears significant, showing a scarce flight capacity.

Castanea Mill.

C. sativa Mill., a subatlantic submediterranean element, is frequent in oak woods on sandstone, mainly in humid and colder sites.

In spite of a good presence of trees behind the trap, the pollination curve is not very significant, presenting a maximum at the end of June of only 82.349 pollen grains m^2/d .

On the other hand the deposited pollen is rather noticeable (9.540 pollen grains m^2/d), even considering its small size; this might be due to the particular position of the trap, just below the emitting sources.

Discussion

The maximal presence of airborne pollen corresponds well with the anthesis

periods near the trap. Generally, the pollen appears in the atmosphere some time before the anthesis and persists rather long after its end. This because the trap is located between the town and the Karst, intercepting pollen deriving from both early and late blooming populations. In the plurispecific taxa, such as *Quercus*, the pollination peaks correspond to the different anthesis maxima of the single species. Sometimes, also in monospecific taxa, secondary peaks are evident, which might be due to contributions from the Karst Plateau or from even further zones, such as the interior Karst or the Julian Alps. This is the case of most anemophytic taxa, with easily aerotransported pollen, such as *Corylus* and *Ostrya*, and/or with early blooming (*Corylus*, *Alnus*, *Ulmus*, *Salix*); such taxa release the pollen before the emission of the leaves, which facilitates its long-distance aerial transport. The persistence of certain pollen types may be also ascribed to re-transport of the already deposited pollen.

Generally, the studied taxa are well represented in the pollen spectra. *Corylus*, *Alnus* and *Platanus* are even over-represented, with respect to their frequency in the survey area, whereas the high values of *Ostrya*, *Quercus* and *Fraxinus* are easily explained by the massive presence in the area of these anemophilous trees. Particularly under-represented are *Tilia* and *Castanea*; the latter has a very small, easily transported pollen; these two species, however, are entomophilous.

The pollen captured by the HFU is rather scarce for all taxa. The deposition is highest in correspondence with the maxima of airborne pollen, but it is significant only for *Ostrya*, *Quercus*, *Fraxinus* and *Castanea*. This seems to be due to the presence, in the proximity of the trap, of overhanging individuals of the same taxa. On the other hand, extremely scarce is the pollen deposition of *Salix* or *Alnus*, whose first individuals are at a few kilometers from the trap. In these cases, the deposition maxima do not correspond to those of airborne pollen, and are probably due to rainfall. The pollens of *Corylus*, *Ulmus* and *Platanus* are very little represented in the HFU in spite of the high presence of airborne granules and the relative vicinity of the emitting sources, presumably because of their good flighting capacity.

Even for the peculiar climatic characteristics of the zone (Polli, 1970), there are no constant correspondences between quantity of transported and deposited pollens, and meteorological factors. Not always does the rain determine an accumulation of pollen in the HFU, also because its action is limited to the initial rain (Mandrioli et al., 1975). The wind does not always facilitate the pollen transport; sometimes there is (e.g. in *Corylus* at the end of February) a deposition increment corresponding to strong winds, especially when these are not constant. Other times the correspondence is noticeable, as at the end of March, when the rain produces deposition maxima for taxa located far from the trap, such as *Alnus* and *Salix*, with a corresponding drop of airborne pollen. The decrease at the end of April, which occurs between two pollination peaks in VFU (e.g. *Ostrya* and *Quercus*), corresponds with a period of weak wind, strong precipitations, and high relative humidity, that inhibit pollen release and its atmospheric dispersal.

Comparing the pollination curves of the outskirts with those of the town center (Rizzi Longo and Coassini Lokar, 1985), the importance of the position of the trap

becomes evident. In the center, where the trap is rather far from the emitting sources, the pollination peaks are wider (e.g. *Quercus*, *Fraxinus* and *Platanus*) and more delayed in respect with the anthesis periods (e.g. in *Ostrya* and *Platanus*), since they result from the pollen contributions from all directions, and are free from the effects of neighbouring individuals. In the outskirts the peaks are sharp and narrow; the contributions from longer distances have a more limited importance. In *Corylus*, however, the pollination curves in the town and in the outskirts are perfectly correspondent: besides the good pollen dispersal this might be due to its optimal transport, the anthesis occurring when the vegetation is still bare.

Conclusions

The anthesis periods, the frequency of the taxa in the survey area and the distance of the emitting sources from the trap are important factors for the interpretation of the pollination curves. In aerobiological studies devoted to the analysis of allergenic pollens, the position of the trap has to be rigorously central with respect to the survey area and far from emitting sources. For other types of studies such as the research of correlations between vegetation and pollen spectra, or between production, release, dispersal and deposition of pollen, the trap should be located within the vegetation or at a small distance from it.

In our case, there is a generally good correspondence between local blooming and maxima of airborne pollen, and a scarce deposition. The latter is high only for trees close to the trap.

The climatic factors have a secondary importance on the interpretation of the pollination curves, especially when the traps are too close to the emitting sources; in this case the pollen production and consequent release are determinant, while the transport or the deposition rate, which are most dependent on meteorological factors, are less important.

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SECONDO CONTRIBUTO ALLA CONOSCENZA DELLA DISTRIBUZIONE DEI MIXOMICETI NEL CARSO TRIESTINO

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Abstract: *SECOND CONTRIBUTION TO THE KNOWLEDGE OF MYXOMYCETES IN THE TRIESTE KARST.* 34 species of Myxomycetes are reported from the Trieste Karst (north eastern Italy), 25 are new to the survey area, 11 are new to Italy.

Keywords: Myxomicetes, Karst, Trieste, Flora.

Introduzione

In due precedenti lavori (Cebulec and Pertot, 1985; Bersan, 1986) sono state segnalate 68 specie di mixomiceti per il territorio carsico. Negli anni successivi sono stati esplorati gli ambienti a copertura arborea ed arbustiva, sia di impianti artificiali che di boschi spontanei. Inoltre sono stati coltivati dei plasmodi a scopo didattico, usando scorza di alberi, lettiera e steli erbacei; molto di questo materiale ha dato spesso origine a fruttificazioni di specie effimere e di piccolissime dimensioni.

Lo stato attuale delle conoscenze a livello nazionale è notevolmente migliorato in tempi recenti; dal 1968 ad oggi sono stati pubblicati numerosi lavori, sia di tipo floristico (Orsino 1981, Orsino e Traverso 1983, Pirola 1968; Pirola e Credaro 1971, 1984, 1986), che ecologico (Pirola e Credaro 1975, Pirola e Credaro lav. in cds).

I risultati di questo studio hanno permesso di migliorare notevolmente le conoscenze dei mixomiceti del Carso triestino con la scoperta di 25 specie non riportate nel contributo precedente, di cui 11 sono nuove per la Flora italiana.

Al momento attuale il territorio carsico che circonda la città di Trieste risulta dominato dalla presenza, nel paesaggio vegetale, di impianti artificiali a *Pinus nigra*; quest'albero, non essendo sempre adatto agli habitat impostigli è facile preda sia di funghi che di animali (Poldini 1980,a); inoltre gli incendi, che durante l'estate spesso bruciano vaste aree di bosco, contribuiscono a danneggiare ulteriormente questi impianti e soprattutto quelle piante che in passato sono state sfruttate per la

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raccolta della resina. Tutti questi fattori, uniti al forte vento che durante l'inverno spazza l'altipiano abbattendo gli alberi più danneggiati, contribuiscono a rendere il bosco di conifere ricco di legno marcescente al suolo.

Le latifoglie spontanee normalmente, sono condotte a ceduo per uso combustibile della legna ricavata (il legno di pino non è gradito perché sporca molto le canne fumarie) con il risultato che in questi ambienti si trova poca legna marcescente di latifoglie a terra. Inoltre, anche dove il bosco viene mantenuto ad alto fusto, gli alberi non sono ancora tanto grandi da perdere rami abbastanza grossi per opera di funghi parassiti.

Descrizione delle stazioni di raccolta

Sono state visitate 23 stazioni di raccolta, di cui 14 in ambiente di latifoglie spontanee, 6 in impianti di conifere (*Pinus nigra*), 1 in impianto di *Fagus sylvatica* (tuttavia le raccolte sono state fatte su legno di conifera portato incidentalmente), e 2 in ambienti antropizzati: una dolina coltivata in località Opicina e l'Orto Botanico dell'Università con le zone verdi nelle immediate vicinanze; in appendice viene dato l'elenco con i numeri di riferimento per la lista floristica, ed inoltre, un elenco delle principali cenosi visitate. Per individuare quest'ultime si è fatto uso delle pubblicazioni di Codogno (1977), Lausi and Poldini (1962), Poldini (1980 a, b; 1985).

Le prime 5 stazioni in ambiente coniferato (S.1-S.5) sono molto simili tra loro; si tratta di vecchi impianti di *Pinus nigra* su terreno prevalentemente pianeggiante; con abbondante lettiera e molti tronchi a terra in avanzato stato di degrado. Lo strato arbustivo è costituito in alta percentuale da *Ostrya carpinifolia* con presenza più o meno marcata di *Quercus pubescens*, *Fraxinus ornus*, *Prunus mahaleb*, e qualche pianta sporadica di *Acer campestre*; le doline che vi si aprono hanno copertura arborea oppure più frequentemente alto arbustiva di latifoglie autoctone. La stazione S.6 è una piccola dolina al confine tra un impianto di *Fagus sylvatica* ed uno di *Pinus nigra*, nella quale sono state gettate alcune grosse ceppaie di *Pinus nigra* provenienti dal suddetto impianto; la stazione S.5, situata a poche centinaia di metri di distanza, è costituita da una catasta di grossi tronchi di *Pinus nigra* molto degradati sul bordo di un altro vecchio impianto. La settima stazione (S.7), è situata nel territorio comunale di S. Dorligo, a circa 200 m s.l.m. in un impianto artificiale di *Pinus halepensis* in forte pendenza ed esposto a W; una sporgenza del M. Carso lo tiene relativamente riparato dal vento di Bora. Lo strato arbustivo presenta caratteristiche analoghe alle pinete citate pocanzi. Le prime sette stazioni sono ubicate su substrati carbonatici con pietre affioranti e molti fenomeni di carsismo epigeo. La dolina presso l'incrocio fra la strada tra Prosecco e Opicina e quella per B.go Grotta Gigante (S.8) si apre in un impianto artificiale di *Pinus nigra* molto vecchio, che però non scende dall'orlo della dolina stessa, per cui appena sotto di questo vi si trova una vegetazione spontanea di *Ostrya-Quercetum pubescentis* sul versante esposto a S, e di *Asaro-Carpinetum* (S.8a) che sfuma in *Galantho-*

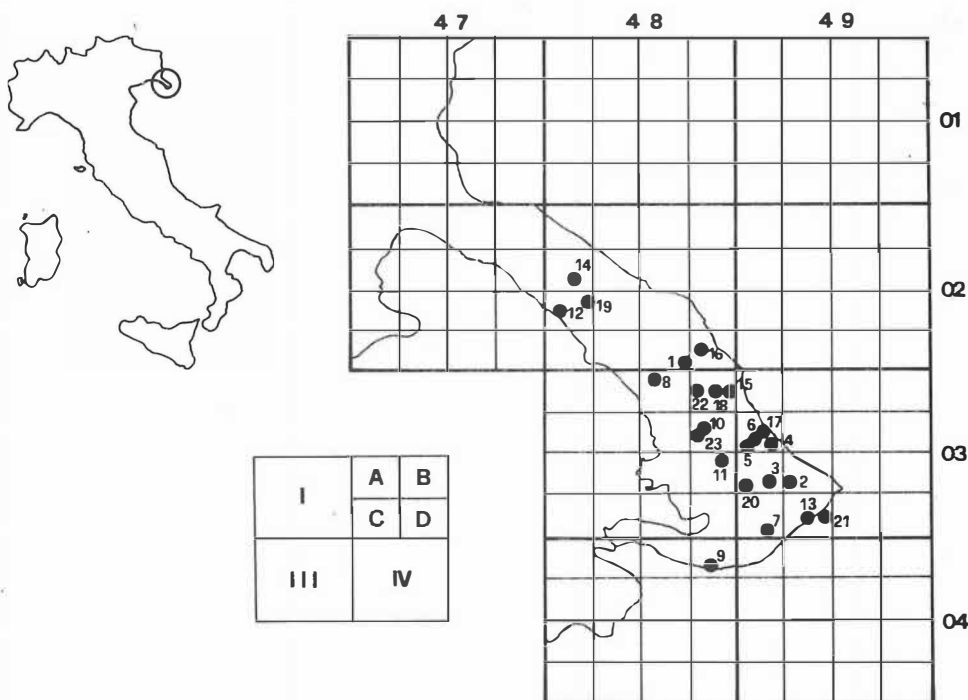


Fig. 1 - Ubicazione delle stazioni sul territorio suddiviso secondo Poldini e Vidali 1981

Coryletum (S.8,b) salendo, sul versante esposto a N. La stazione in località Vignan (S.9), Comune di Muggia, si trova su di una collina-marnoso arenacea (Flysch) sulla riva destra del torrente Menariol; le raccolte sono state effettuate in *Seslerio-Quercetum petraeae*. Le stazioni di M. Valerio (S.10, 150 m s m) e torrente Farneto (S. 11), benché con esposizione molto diversa (la prima a W-NW e la seconda a E-NE), presentano vegetazione e substrato simili alla stazione precedente; inoltre la stazione (S.11) presenta una pendenza molto marcata per cui le varie raccolte sono state effettuate in un intervallo di altitudine di circa 100 m. La stazione S. 12 sita in Aurisina, è stata scelta per la presenza di dell'*Ostryo-Quercetum ilicis*; il substrato è costituito da roccia carbonatica. La stazione S.13, a Botazzo, è un coltivo abbandonato su substrato marnoso arenaceo (Flysch) a lato della strada bianca che costeggia il torrente Rosandra; si trova in posizione ben riparata ed esposta al sole e la sua vegetazione può essere inclusa in *Clematido vitalbae-Rubetum ulmifolii*. La stazione di S. Pelagio (S.14), è un inghiottitoio cui si accede da una caverna; la vegetazione del fondo appartiene al *Lamio orvala-Sambucetum nigrae*. La stazione di Trebiciano si trova in prossimità della ex discarica comunale ed è protetta dalla Bora dalla collinetta di materiali che attualmente la ricopre; essa può essere divisa in due (S.15 a) *Ostryo-Quercetum pubescentis*, la parte a cavallo dell'orlo della

dolinetta esplorata, e (S. 15 b) *Galantho-Coryletum*, il fondo della stessa; il substrato è roccia carbonatica con molte rocce affioranti.

Le stazioni di Monrupino (S.16), Bristie (S.19), Gropada (S.17), Strada per Basovizza (S.20) e Banne (S.18), hanno vegetazione di *Ostryo-Quercetum pubescentis* su substrato carbonatico. La stazione di Kosina (S.21) è un deposito di cortecce e segature di una vicina fabbrica di manufatti legnosi sita in territorio jugoslavo; le raccolte sono state fatte in *Ostryo-Quercetum pubescentis*, nel quale sono rotolate delle cortecce e frammenti legnosi di *Pinus nigra*. Il substrato è dato da roccia carbonatica. La faggeta di Basovizza (S.20) è un impianto artificiale di *Fagus sylvatica* e *Abies cephalonica* in cui al momento attuale sopravvivono ormai soltanto i faggi; situato in prossimità del crinale carsico, confina con un *Ostryo-Quercetum pubescentis* nel quale si sono inseriti spontaneamente alcuni pini neri. Le doline di via Assenzio a Opicina (S.22) è un ambiente abbastanza antropizzato. Il fondo di questa dolina, ombreggiato da un boschetto a *Quercus petraea*, viene periodicamente pulito da tutti gli arbusti e le ramaglie, che vengono ammucciate in un angolo. Siccome confina con un orto, può inoltre beneficiare di un notevole apporto idrico durante la stagione secca. Il substrato è terra rossa e roccia carbonatica. L'Orto Botanico e le aiuole del Dipartimento di Biologia dell'Università di Trieste (S.23) costituiscono l'ultima stazione di raccolta; questo è un ambiente molto antropizzato dove la vegetazione subisce diradamenti e potature anche drastiche per poter lasciare agibili i vialetti pedonali che collegano i vari Istituti. Ciò rende piuttosto vulnerabili ai funghi (*Ganoderma appalanatum*, *Armilariella mellea*, *Phellinus punctatus*, *Inonotus hysspidus*, *Ustulina deusta*, *Nectria cinnabarina* nella forma conidica *Tubercularia vulgaris*) le piante sopravvissute e crea un habitat favorevole ad alcune specie di mixomiceti. Le località di raccolta, sono state scelte in funzione della vicinanza all'Università, della presenza di particolari essenze arboree ed arbustive, e per le peculiari caratteristiche microclimatiche di alcune di esse, cercando di visitare il maggior numero di ambienti possibili pur facendo un numero di esplorazioni comparabile. I motivi che hanno portato a questa scelta sono emersi dalla considerazione di lavori precedenti che hanno trattato argomenti simili in altre provincie italiane, mettendo in risalto la presenza di fruttificazioni in ambienti antropizzati (Orsino 1981), soprattutto dove un regime idrico controllato artificialmente, unito spesso ad un apporto di nutrienti organici (concimature, pacciamature ecc.), ne favorisce la proliferazione. Per quanto riguarda l'altitudine di raccolta all'interno delle doline, è stata considerata quella dell'orlo, annotandone il dislivello della stazione di raccolta qualora questo superasse i 10 m. Le raccolte, qualora non specificato altrimenti, sono state effettuate dall'autore.

Dati e metodi

Al fine di ottenere il maggior numero di specie per località esplorata, oltre alle raccolte di campagna, sono stati raccolti frammenti di vari tipi di substrato (scorza d'albero, steli erbacei vivi e morti, liane, lettiera ecc.) e messi in coltura con il

metodo della "camera umida" (Mitchell 1978, Pando e Lado 1987). In molti casi le fruttificazioni sono state rimosse dal substrato non appena mature e montate in "Hoyer medium" continuando la coltura del substrato rimasto. La temperatura delle colture è stata quella ambiente, con un minimo di 15 °C ed un massimo di 24 °C. La metodica ha previsto l'uso di piastre Petri di 10 cm di diametro e di 10 mm di altezza sul quale fondo sono stati posti due dischi di carta da filtro da 9 cm di diametro.

Il frammento di substrato, di dimensioni adeguate al contenitore, è stato bagnato abbondantemente con acqua bidistillata previo minuzioso controllo di eventuali presenze e relative posizioni di fruttificazioni già mature ad un ingrandimento 25x, poi, al fine di ottenere il massimo di specie per ogni piastra, è stato messo a incubare in ambiente buio (Pando e Lado 1987). Normalmente dopo tre ore, l'acqua in eccesso è stata eliminata inclinando la piastra; tuttavia in alcuni casi, è stata lasciata per un tempo superiore, fino ad un massimo di otto ore. In quest'ultimo caso, le piastre sono state esaminate minuziosamente prima e dopo l'eliminazione dell'acqua in eccesso, per verificare l'eventuale presenza di specie effimere da togliere dal substrato e montare immediatamente su vetrino; in ogni caso, le fruttificazioni più rapide sono maturate soltanto dopo alcuni giorni dall'inizio della coltivazione.

Complessivamente sono state esplorate direttamente in campagna, oppure coltivando diversi substrati in laboratorio, 23 stazioni: 14 stazioni di raccolta con vegetazione spontanea, 7 impianti forestali e 2 ambienti antropizzati, in cui si sono raccolti complessivamente 43 campioni, che con i 32 ottenuti in laboratorio hanno dato un totale di 75. Di questi, 36 campioni (49.33%) provengono da legno di pino, 13 campioni (17.33%) provengono da legno di latifoglie, 16 campioni (21.33%) da scorza di piante vive, 1 da lettiera di conifera (0.01%) e 8 campioni (10.66%) da lettiera di latifolia. Delle 32 raccolte di campagna su legno morto, 27 sono riferiscono a pino e 5 a latifoglie. La lista floristica è compilata in ordine sistematico (Alexopoulos and Martin 1969, Lakampal and Mukerji, 1981); per le *Stemonitaceae*, è stata adottata la nomenclatura di Nannenga Bremekamp (1974); per la determinazione delle specie coltivate in camera-umida sono state usate le chiavi analitiche di Mitchell (1978, I - II).

Lista floristica

Licea minima Fr.

- S.1, I.A., camera umida, legno decorticato di *Pinus nigra* con alghe e licheni raccolto il 06/01/1987, fruttificazioni maturate il 01/02/1987. - S.8b, C.3, camera umida, scorza di *Corylus* raccolta in dolina, 287 m s.l.m. -10 m, il 22/02/1987, fruttificazioni maturate il 7/03/1987. - S.2, I/A/, 3/07/1987 e 22/02/1988 su *Pinus nigra*. - S.3, I.A., 7/07/1987 su *Pinus nigra*. - S.7, I.A. camera umida, legno decorticato di *Pinus sp.* raccolto il 24/01/1988, fruttificazioni maturate 1/02/1988.

Specie di piccolissime dimensioni, forma fruttificazioni sparse su legno decorticato di *Pinus nigra*; specie nuova per il Carso.

Licea variabilis Schrad.

- S.4, I.A. 6/03/1988 su *Pinus nigra*.
Specie nuova per il Carso.

Reticularia olivacea (Ehremb.) Fr.

- S.4, I.A., 1/06/1987, 27/06/1988 su tronchi di *Pinus nigra* accatastati da molti anni.

La stazione di raccolta di questa specie è caratterizzata dalla presenza di vecchie cataste di grossi tronchi di *Pinus nigra* decorticati e coperti da alghe, muschi e licheni; in questa zona sono stati fatti degli esperimenti di impianto di conifere anche non europee. Specie nuova per il Carso.

Cribraria argillacea Pers.

- S.4, I.A., 15/06/1987 su *Pinus nigra*. - S.5, I.A., 30/06/1987 su *Pinus nigra*. - S.2, I.A., 3/07/1987 su *Pinus nigra*. - S.8,c, 16/06/1988 su *Pinus nigra*.

Questa specie sta diffondendosi in quelle pinete danneggiate dagli incendi e nelle stazioni più umide e fresche.

Cribraria languescens Rex

- S.5, I.A., 1/07/1987 su *Pinus nigra*. - S.4, I.A., 1/07/1987 su *Pinus nigra*. - S.2., I.A., 3/07/1987 su *Pinus nigra*. - S.3., I.A., 7/07/1987 su *Pinus nigra*. - S.7., I.A., camera umida, legno decorticato di *Pinus halepensis* raccolto il 24/01/88, fruttificazioni maturate il 6/02/1988; - ibid., stessa matrice, fruttificazioni maturate il 19/02/1988.

Questa specie si trova su legno di *Pinus*, decorticato e molto degradato in località molto umide; tende a fruttificare all'interno delle gallerie lasciate dalle larve; le ragioni per cui due piastre con lo stesso substrato, raccolte nello stesso sito, alla medesima esposizione e altitudine, non siano maturate allo stesso tempo, sono ancora ignote. Questa specie, appena maturata, presenta colorazione che tende al violaceo e che vira ad un bruno ramato dopo qualche tempo. Nuova per l'Italia.

Cribraria piriformis Schrader

- S.1., I.A., 6/07/1987 su *Pinus nigra*. - S.21, C.5, 28/06/1987, su *Pinus nigra*. - S.5, I.A., 3/07/1987 su *Pinus nigra*. - S.8,b, C.3, 287 m s.l.m. -10 m, 16/06/1988 su *Pinus nigra*.

Tutte le raccolte sono state fatte su tronchi di *Pinus nigra* molto degradati; la raccolta di B.go Grotta proviene da un tronco giacente in mezzo ad un boschetto di *Corylus* ed stata fatta assieme a quella di *Cribraria argillacea*.

Cribraria violacea Rex

- S.9, C.4, camera umida, scorza di *Fraxinus ornus* raccolto il 4/01/1987, fruttificazioni maturate il 11/03/1987. - S.12, C.7, camera umida, scorza di *Fraxinus ornus* raccolto in ambiente mediterraneo 100 m s.l.m., il 22/02/1987, fruttificazioni maturate il 14/04/1987; - ibid., stessa matrice, raccolta il 17/03/1987, fruttificazioni maturate il 2/04/1987. - S.18, C.5, camera umida, podezi di *Cladonia pocillum* (Lichenes) crescenti sopra legno di *Ostrya carpinifolia* raccolti il 17/03/1987, fruttificazioni maturate il 2/04/1987. - S.23, A.A., camera umida, scorza di *Diospiros kaki* molto vecchio raccolta il 10/02/1988,

fruttificazioni maturate il 22/02/1988.

Non ci sono raccolte di campagna, la specie è nuova per il Carso.

Cribraria vulgaris Schrader

- S.7, I.A., camera umida, campione di legno decorticato di *Pinus* (cfr *halepensis*) raccolto il 06/05/1987, fruttificazioni maturate il 1/07/1987.

La specie nuova per il Carso.

Perichaena corticalis (Batsch) Rostaf.

- S.12, C.7, camera umida, scorza di *Quercus ilex* raccolta il 24/03/1987 100 m s.l.m., in ambiente mediterraneo, fruttificazioni maturate il 9/05/1987. - S.2, I.A., su scorza di *Fraxinus ornus* morto, in dolina, appena sotto il margine, 1/06/1987.

Sia la raccolta di campagna che la fruttificazione in camera umida consistono di pochi sporangi sparsi; la stazione di raccolta in campagna è piuttosto riparata dal vento ed esposta a sud; la specie è nuova per il Carso.

Perichaena vermicularis (Schwein.) Rostaf.

- S.22, A.A., camera umida, steli secchi di *Stachys* sp. raccolti in dolina il 05/01/1987, fruttificazioni maturate il 12/03/1987. - S.15-a, C.5, camera umida, scorza di *Fraxinus ornus* raccolta il 19/04/1987, fruttificazioni maturate 1/06/1987.

Il substrato è stato raccolto in posizioni riparate ed esposte a sud; queste vanno soggette però, per tutto il periodo invernale, a temperature piuttosto basse; ciò contrasta in parte con la presunta termofilia citata in lavori precedenti dove peraltro vengono citate soltanto raccolte di campagna (Bersan, 1986; Orsino e Traverso, 1981). La coltivazione di plasmodi su steli erbacei presenta notevoli difficoltà a causa del gran numero di colonie di eumiceti che vi si sviluppano e richiedono per la loro eliminazione un continuo controllo delle colture.

Arcyria cinerea (Bull.) Pers.

- S.1, I.A., camera umida, scorza di *Quercus* raccolta il 12/04/87, fruttificazioni maturate il 18/04/1987. - S.20, C.5, camera umida, tronchetto di *Clematis vitalba* raccolto il 21/03/87 a lato della grande curva sulla strada per Basovizza, 320 m s.l.m., fruttificazioni maturate il 18/04/1987. - S.15-b, C.3, camera umida, scorza di *Corylus* raccolta in dolina il 19/04/87, fruttificazioni maturate 1/06/1987. - S.5, I.A., su *Pinus nigra* 30/06/1987. - S.11, C.4, camera umida, scorza di *Fraxinus ornus* raccolto il 5/06/87, fruttificazioni maturate 11/07/1987.

Specie comunissima presente spesso anche nelle colture.

Arcyria pomiformis (Leers) Rostaf.

- 2.10, C.4, 6/07/1987 su *Quercus petraea* e - 22/06/1988 su legno decorticato di latifolia.

Queste raccolte, al contrario delle altre (Bersan, 1986), provengono da legno di latifoglie autoctone e non da conifere.

Echinostelium minutum De Bary

- S.8-a, C.6, camera umida, scorza di *Carpinus betulus* morto, raccolta in dolina, 287 -15 m s.l.m., il 5/04/1987, fruttificazioni maturate il 18/04/1987, fruttificazioni maturate il 18/04/1987. - S.16, C.4, camera umida, scorza di *Fraxinus ornus* raccolta il 3/04/1987, fruttificazioni maturate il 23/04/1987.

Specie di piccole dimensioni, ha brevissima durata per la scarsità di capillizio

che non riesce a trattenere le spore; le dimensioni e la forma di quest'ultimo sono molto variabili, come variabile è anche il colore delle spore (da bianco a rosa pallido). La specie è nuova per l'Italia.

Clastoderma debaryanum Blytt

- S.8-a, C.6, camera umida, scorza di *Carpinus betulus* morto raccolta in dolina 287 -15 m s.l.m., il 22/02/87, fruttificazioni maturate il 7/03/1987; - ibid., stessa matrice, fruttificate il 12/03/1987; - ibid., su scorza di *Euonimus* fruttificate il 06/04/1987. - S.4, I.A., 08/09/1987 su ramo marcescente di *Pinus nigra*; legit. E. Gracia.

La specie è nuova per l'Italia.

Brefeldia maxima (Fr.) Rost.

- S.14, C.1, ceppo di *Sambucus nigra* in antro dentro un inghiottitoio 14/04/1988; legit. L. Fungone et A. Dolzani.

L'etallio nero in completa deiscenza misurava più di 10 cm di diametro, e 2 cm di altezza; macroscopicamente identico ad *Amaurochaete atra*. specie relativamente comune in Carso.

La specie, nuova per il Carso, ci risulta già segnalata per l'Italia (Berlese, 1888).

Amaurochaete atra (Alb. et Schwein.) Rostaf.

- S.2 I.A., 14/06/1988, su *Pinus nigra* ancora in piedi; - ibid., su catasta di tronchi di *Pinus nigra* tagliati di recente 13/05/1988. - S.20., su tronco di *Pinus nigra* morto ma ancora in piedi, 14/05/1988.

Come le precedenti (Bersan, 1986), anche queste raccolte confermano l'ecologia peculiare di questa specie.

Macbrideola cornea (G. Lister et Cran) Alexop.

- S.23, A.A., camera umida, scorza di *Acer pseudoplatanus* raccolto il 13/02/87, fruttificazioni maturate il 7/03/1987.

Il campione è scarso, i pochi sporangi, per tipici, sono stati montati in Hoyer medium. La specie è nuova per l'Italia.

Paradiacheopsis fimbriata (G. Lister et Cran) Hertel

- S.23, A.A., camera umida, frammento di legno di *Tilia cordata* raccolto il 20/02/87 fruttificazioni maturate il 28/02/1987. - S.16, C.4, camera umida, scorza di *Quercus cerris* raccolta in dolina il 18/12/1988, fruttificazioni maturate il 25/12/1988.

Le fruttificazioni del 12/88, sono in parte conservate secche ed in parte montate in Hoyer; la specie è nuova per l'Italia.

Comatricha elegans (Racib.) Lister

- S.5, I.A., 09/06/1988 su *Pinus nigra* coperto da *Corticiaceae* (Fungi).

Dal 1983 in poi questa specie è stata trovata ogni anno, ma sempre in esemplari isolati e molto rovinati dai basidiomiceti sui quali aveva fruttificato, per cui non è stata mai conservata; segnalazione nuova per il Carso.

Comatricha pulchella (C. Bab.) Rostaf. var. **fusca** A. Lister

- S.10, C.4, su foglia morta di *Quercus petraea* 17/06/1988

La colorazione molto scura delle spore in massa, lo stipite piuttosto corto e le spore grigiobruno e non rosabrune a luce trasmessa (Nannenga Bremekamp, 1974), fanno propendere per questa determinazione.

La varietà è nuova per la Flora italiana.

Lamproderma arcyriodes (Sommerf.) Rostaf.

- S.17, C.5, in dolina su foglie morte di *Quercus* 27/09/1987; legit. L. Fungone.

La specie è nuova per il Carso.

Lamproderma arcyrionema Rostaf.

- S.6, I.A., 10/07/1987 su *Pinus nigra*.

Raccolta relativamente abbondante, su legno decorticato ma non degradato.

Specie nuova per l'Italia.

Lamproderma columbinum (Pers.) Rostaf.

- S.4, I.A. tronco di *Pinus nigra* marcescente, 9/03/1988.

Specie nuova per il Carso.

Leocarpus fragilis (Dickson) Rostaf.

- S.20, C.5, 10/06/1987 su lettiera di latifoglie. - S.4, I.A., 25/06/1987 su tronco decorticato di *Pinus nigra*.

Due sole raccolte, relativamente vicine geograficamente, però in ambiente microclimaticamente piuttosto diverso: la stazione S.20 è situata su un pendio esposto a sud sotto il crinale dell'altipiano, con una vegetazione piuttosto termofila che presenta le caratteristiche dell'*Ostryo-Quercetum pubescentis* (Ht.) Trinajstić 74, mentre la stazione S.4 è una pineta stramatura con tronchi di oltre 30 cm di diametro che sovrasta un ceduo di *Ostrya* allo stato arbustivo.

La specie è nuova per il Carso.

Craterium leucocephalum (Pers.) Ditmar

- S.17, C.5, in dolina su lettiera di *Quercus* 27/09/1987, legit. L. Fungone.

Questa raccolta, piuttosto abbondante, ha scarse concrezioni calcaree sulla parte superiore dello sporangio.

Physarum cinereum (Batsch) Pers.

- S.3, I.A., 7/07/1987 su *Pinus nigra*. - S.23, A.A., il 27/02/1988, su lettiera di latifoglie coltivate; legit. M. Grahonia.

Il plasmodio bianco delle dimensioni di circa dieci metri quadrati ha suscitato la curiosità dei giardinieri dell'Orto Botanico; ciò ha permesso l'osservazione del

fenomeno fino alla maturazione degli sporangi. Il prato prospiciente l'aiuola sulla quale si sono sviluppate le fruttificazioni era stato di recente trattato con concimi sintetici; analoghi fenomeni si sono riscontrati in un giardino di Trieste a 100 m s.l.m., dove fruttificazioni delle dimensioni di 30 cm e più di *Fuligo septica* hanno incuriosito i proprietari, e nel giardino di una scuola materna sempre a Trieste (Altura 100 m s.l.m.), dove tutte le pacciamature degli alberi, trattate senza parsimonia con batteri liofilizzati, presentavano plasmodi molto estesi che hanno dato origine a fruttificazioni etaloidi sempre di *Fuligo septica* superiori a mezzo metro di diametro; esiste un campione d'erbario delle due raccolte di *Fuligo*, ed esiste un campione per ogni tipo di substrato coperto dalle fruttificazioni di *Physarum* compresi i sassi.

La specie è nuova per il Carso.

Physarum flavicomum Berk.

- S.20, C.5, Plasmodio giallo vivo, raccolto su *Pinus nigra* e su lettiera il 01/06/1987, fruttificazioni mature il 3/06/1987. - S.4, I.A., tronco di *Pinus nigra* degradato 15/06/1987.

Specie nuova per l'Italia.

Physarum lateritium (Berk. et Rav.) Morgan

- S.10, C.4, su foglia di *Q. pubescens* morta, appoggiata ad un ramo caduto, 17/06/1988.

La raccolta è stata effettuata in *Seslerio-Quercetum petraea* (rilievo n. 5, Codogno, 1977).

La specie è nuova per l'Italia.

Physarum psittacinum Ditmar

- S.1, I.A., su *Corylus* in dolina, il 9/06/1987. - S.5, I.A., 22/06/1988 su *Pinus nigra*.

Nel fresco il peridio presenta iridescenze lilla azzurre, poi invecchiando assume una colorazione brunastra; il gambo ed i nodi del capillizio presentano colorazione rosso aranciato molto vivo anche dopo un anno.

La specie è nuova per il Carso.

Diderma cinereum Morgan

- S.19, C.5, camera umida, plasmodio bianco raccolto su lettiera di *Quercus pubescens* in dolina in *Ostryo-Quercetum pubescentis* il 14/02/1988, fruttificazioni mature il 19/02/1988.

La specie è nuova per l'Italia.

Didymium anellus Morgan

- S.12, C.7, camera umida, scorza di *Fraxinus ornus* raccolto in ambiente mediterraneo il 17/03/1987, fruttificazioni mature il 18/04/1987.

La specie è nuova per l'Italia.

Didymium minus (Lister) Morgan

- S.11, C.4, 13/07/1987 su lettiera in *Seslerio-Quercetum petraeae*.

Didymium nigripes (Link) Fr.

- S.23, A.A.; il 16/06/1988 su ramo morto di *Pinus nigra*, legit., W. Bergamini.

Didymium squamulosum (Alb. et Schw.) Fr.

- S.13, C.2, su steli erbacei di *Clematis vitalba* e *Rubus ulmifolius*. - S.23, A.A., il 27/02/1988, su lettiera di *Cryptomeria japonica*.

La raccolta dell'Orto Botanico è stata fatta a pochi metri dalla aiuola invasa da *Physarum cinereum*.

La specie è nuova per il Carso.

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Riassunto

34 specie di Mixomiceti sono segnalate per il Carso triestino, alcune raccolte in campagna, altre sviluppate da colture in "Camera Umida" con materiale proveniente da substrati diversi; 25 sono nuove per il Carso triestino, 11 sono nuove per la Flora italiana.

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Elenco delle stazioni espolorate

	cenosi	altitudine
(S. 1) - Opicina Campagna.	I.A.	300
(S. 2) - Pineta sotto il M. Grociana.	I.A.	425
(S. 3) - Pineta presso la "Foiba di Basovizza".	I.A.	380
(S. 4) - Sentiero N° 3 presso Basovizza.	I.A.	400
(S. 5) - Pineta sulla strada tra Basovizza e Padriciano.	I.A.	375
(S. 6) - Faggeta sulla strada tra Basovizza e Padriciano.	I.A.	375
(S. 7) - S. Dorligo.	I.A.	250
(S. 8) - Dolina presso l'incrocio della strada per B go Grotta Gigante; a), b).	C 6, C 3	287, 275
(S. 9) - Vignan (Muggia).	C 4	15
(S. 10) - M. Valerio.	C 4	150
(S. 11) - Greto del Torrente Farneto.	C 4	150
(S. 12) - Aurisina.	C 7	100
(S. 13) - Botazzo.	C 2	187
(S. 14) - S. Pelagio.	C 1	250
(S. 15) - Trebiciano; a), b).	C 5, C 3	325, 317
(S. 16) - Monrupino, a destra della strada per Ferneti.	C 5	320
(S. 17) - Gropada	C 5	400
(S. 18) - Banne	C 5	300
(S. 19) - Bristie	C 5	150
(S. 20) - Grande curva sulla Strada per Basovizza	C 5	320
(S. 21) - Kosina (JU), deposito di segature.	C 5	425
(S. 22) - Dolina di via Assenzio.	A.A.	320
(S. 23) - Orto Botanico dell'Università e zone limitrofe antropizzate (M. Valerio, 120 msm).	A.A.	120

I.A. = impianto artificiale

A.A. = ambiente antropizzato

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